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# THE EFFECT OF EMOTIONAL STIMULI ON THE GASTRO-INTESTINAL MUSCULAR TONE

by

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# VITA

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# The Effect of Emotional Stimuli on the Gastro-Intestinal Muscular Tone.

## I. Introduction.

The work to be here reported is aimed toward experimental test of the theory of the emotions that was proposed by James and by Lange (1). Stated in terms of the reaction theory of consciousness (cf. Dunlap (2)), the hypothesis is as follows: When an individual is confronted with an emotionally exciting object or situation ("emotional stimulus") one set of reactions follows directly upon the external receptor stimulation caused by the situation and involves perception of the object or situation. One of these reactions might be the verbal report: "I see a snake", or "There's a snake". Others of these primary reactions end in bodily changes of a diffuse but characteristic sort - vascular changes, contractions and relaxations of smooth muscle organs such as stomach and intestines, secretion of glands, and general changes in the state of the striped musculature, such as trembling or general increased or decreased contractile tone. These bodily changes result in new internal receptor stimulation, which initiates a secondary set of reactions involving the feeling of emotion; and one of these secondary reactions may be the verbal report: "I feel fear", or "I am afraid", while another may be the act of running away.

The crux of the James-Lange theory is then that the bodily changes are the emotion, which is felt just as anything else is felt or perceived, thru receptor stimulation and, according to the reaction theory, the resulting reactions. The driving force of emotions is thus provided by the fund of internal receptor stimulation caused by emotion.

In the test of this bodily-change theory there are two specially important points. That such bodily changes do take place in emotions is generally not denied; but for ultimate establishment of the truth of the theory it must at least be shown, first, that the changes are to some extent characteristic for each emotion - that fear, for example, is characterized

by certain definite bodily states, differing in important respects from those of rage or other emotions; and secondly it must be shown that the characteristic changes precede the feeling of the emotion - that is, precede the report of the emotion's presence, or precede some signal representing such report.

A great deal of work has been done on the vascular changes, which were emphasized by Lange (1), in the attempt to show that they are characteristic for the various emotions; but the impression given by this volume of work is one of great confusion, perhaps because the methods used have not been adequate. The present investigation has been concerned, however, with tone changes (contractions and relaxations) of the stomach and intestines, and was suggested by two not unrelated lines of experimental work in physiology, which are now to be mentioned.

Cannon (3) (4), in studying by the fluoroscopic method the movements of stomach and intestines, mostly in cats. observed the complete stopping of all such movements whenever the animal showed signs of emotional excitement - fear, rage, or distress. Under such conditions the peristaltic contractions disappeared, and the stomach and intestines seemed wholly relaxed. These inhibitory effects were clearly mediated by the splanchnic nerves ((4) p.219), belonging to the sympathetic division of the autonomic or involuntary nervous system ((3) Chap.II). At the times when the digestive contractions and movements could be observed, the animals seemed in a state of quiet contentment, sometimes with purring.

Thus, in what we would call unpleasant emotional arousal, there was found the sympathetic effect of inhibition of gastro-intestinal movements, with loss of tone of the organs; and with pleasant emotional condition is associated sufficient contractile tone of the organs to enable the gastro-intestinal movements to take place. This contractile tone is contributed to by action of the vagus and sacral nerves ((3) p.13, also

Chap. II), which belong to the parasympathetic division of the autonomic system, with action in general opposing that of the sympathetic division.

The second line of experimentation that has been suggestive is represented by the work of Cannon and Washburn ((3) p.255), and the later work of Carlson (5), on the nature of hunger. Washburn learned to swallow a small uninflated balloon attached to a rubber tube. The balloon was then lightly inflated and the tube connected with a water manometer which supported a float recorder. Thus contractions of the stomach could be recorded on a smoked drum. The subject, in a fasting condition, was seated with the recording apparatus out of his sight, but with his hand on a key, which he pressed whenever he felt hunger sensations, thus making a signal on the drum by means of an electromagnetic signal marker. The records showed that when the subject had no hunger sensations there were no contractions of the stomach; and whenever the subject experienced a hunger pang, a vigorous contraction was registered. Moreover, according to the record, the sensation began after the contraction had nearly reached its height and continued a short time after the contraction had subsided, thus indicating that the contraction probably causes the sensation. Carlson corroborated all this, and in addition ((5) p.69) was able artificially to produce strong contractions in the previously quiescent empty stomach by sudden distention of the balloon; and these contractions caused hunger pangs identical with those of the spontaneous hunger periods. This seems a convincing demonstration of the peripheral genesis of the hunger pangs - the contractions cause the sensations.

The present work is an attempt to apply in humans the balloon method, that proved so successful in the investigation of hunger, to the investigation of the emotional gastro-intestinal changes observed in cats by Cannon with the fluroscopic method. Such investigation evidently aims

toward test of the James-Lange bodily-change theory of emotions as far as gastro-intestinal contractile tone is therein concerned. There are three possible steps in the investigation. First, the balloon method must show to what extent gastro-intestinal tone changes (contractions or relaxations) occur in emotion and to what extent they are characteristic for the various emotions. Secondly, thru use of introspective signals such as Cannon and Washburn and Carlson used, it must be tested whether the tone changes precede the feeling of the emotions. And thirdly, the tone changes might be produced artificially by the use of drugs (such as adrenin - cf. Cannon(3) p.36) as additional test whether the feelings are caused by the tone changes.

The first of these steps is mainly represented in the experiments; a small start was made on the second step, the introspective conditions being much more complicated when various emotions are concerned than where it is a question of but a single effect, the hunger pang. The third step does not figure in the results.

The experimental work was approached with a certain expectation, based on Cannon's fluoroscopic observations and consequent preliminary generalizations concerning the role of the two main divisions of the autonomic nervous system, the sympathetic and parasympathetic, in the various emotions. What we would expect is that in unpleasant emotional states the sympathetic effect of loss of gastro-intestinal tone (relaxation) would appear, in pleasant states the parasympathetic effect of increase of tone (contraction). Greater specificity than that we have no reason to expect in advance for the various emotions in connection with the gastro-intestinal tract in general. On this view, if the gastro-intestinal tone changes should ultimately fit into the James-Lange hypothesis, they would be considered to contribute to emotional states little more than feeling tone - pleasantness or unpleasantness, leaving the specificity of emotions to be

accounted for by the more complexly varying vascular conditions (constrictions and dilations) in the different parts of the body (viscera, muscles, skin, etc.) and by striated muscular factors.

## II Rectum.

The method employed did not differ from that used by Cannon and by Carlson in their investigations of the stomach in hunger. The essential point is the introduction of a rubber balloon into a hollow viscus (stomach, duodenum, rectum) and the recording of pressure changes in the balloon by means of an external recording system. These changes indicate active alterations in the shape or "tone" (contractions or relaxations) of the organ under investigation only after allowance is made for changes in general intra-abdominal pressure in consequence of respiratory and other activity (action of diaphragm and muscles of abdomen and thorax). Some indirect check on the intra-abdominal pressure changes is therefore obtained by the use of pneumographs ("respiration recorders"), in these experiments attached both to abdomen and to chest, which directly indicate changes merely in girth.

By the use of this method, then, the attempt was made to study in human reactors what changes occur in the tone of stomach, rectum, and duodenum upon presentation of stimuli reasonably expected to cause emotional reactions of various sorts. Introspective reports were used freely in all experiments as a check upon whether emotional reactions had actually occurred; and an introspective signal was used in a small number of experiments, after the fashion of Cannon and Washburn. In some experiments continuous blood pressure recording was added, two different methods being employed.

## 1. Apparatus

The balloons used in stomach and duodenum were of very thin rubber, about 5 cm. wide when collapsed, and around 17 cm. long. The balloon was attached to a Rehfuss duodenal tube of smooth, firm but flexible rubber, about ½ mm. thick and 120 odd cm. long, in the lower end of which was inserted a regular metal duodenal bulb such as is used in clinical work to introduce fluids into or remove them from the duodenum. This bulb resembles a small olive pit, about 8 to 9 mm. in diameter and 2 cm. long, with a hollow stem to be inserted into the end of the rubber tube. The bulb is pierced with slits, which communicate freely with the lumen of the stem. The bulb, attached to the tube, is inserted in the balloon very nearly up to the blind end, and the open end of the balloon is tied directly around the rubber tubing - firmly enough to make an airtight joint that will not slip, but not so tight as to retard the passage of air thru the tube. In the wall of the tubing within the balloon are cut two or three holes about 2 x 6 mm., so that the lumen of the tube communicates with the interior of the balloon directly, as well as thru the metal bulb, insuring free passage of air. When the air was exhausted from the balloon, the bulk of balloon and tube was at a swallowable minimum. The metal bulb, necessary for duodenal use, was retained for work with the stomach because the experimenter found in his own experience that the bulk of the bulb aided his swallowing reflexes. But there are probably individual differences in this respect, and it might be well in future work to keep on hand the same system made up without the bulb, for trial with subjects who have difficulty with the swallowing.

The balloon for the rectum was similar to the stomach balloon in all respects, except that its length was about 7 cm. It was attached

exactly like the stomach balloon, but to a special metal tube instead of a rubber one. The rectal tube and balloon are shown in Fig. 1. The tube is about 4 mm. in diameter, about 12 cm. long on one side of the curve, and 6 cm. on the other. A closed, blunt, rounded cap is fitted over the end of the tube, and there are three holes of 3 to 4 mm. in diameter in the wall of the tube within the balloon. The balloon is tied firmly around the tube with the aid of a groove filed around the latter. To the open end of the metal tube, of course, is attached a long length of ordinary rubber tubing, about 5 mm. in diameter.

Between each balloon and its recording device was inserted an intermediate pressure chamber, the function of which was to permit the balloon to be blown up without disturbance of the recording device and thus to allow the latter to start at atmospheric pressure - the most sensitive position. The functioning of these chambers will be understood from the following diagrams and descriptions.

In Fig. 2, A is the rectal balloon and tube; B, a small bottle fitted with a two-hole rubber stopper; C, a rubber balloon similar to the rectal balloon, tied, with the aid of a ring of rubber tubing, to a glass tube passing thru one of the holes of the stopper. This tube is connected by rubber tubing with the rectal tube, with a glass T-tube (D) inserted, thru which the system A-C is inflated. The open arm of the T-tube is provided with a short piece of rubber tubing which may be closed off by a spring pinch-cock. Thru the other hole of the stopper passes a second glass tube, communicating with the air in the bottle outside of the balloon (C) and connected to a sensitive, adjustable recording tambour (E) (Lombard pattern, A.H.Thomas Co. #6047). Between bottle and tambour is inserted a glass Y-tube (F) fitted like

the T-tube above. With F open, A and C are inflated, the system B-E remaining at atmospheric pressure by virtue of the opening at F, and the writing point remaining in a zero position, with tambour unstretched. F is now closed off, and then increased pressure on A will expand C, thus increasing the pressure in the system B-E, bulging the tambour membrane and raising the writing lever. Decreased pressure on A will similarly cause a drop of the writing lever.

In the stomach or duodenal system the intermediate chamber consisted in the early experiments of a larger bottle and balloon arranged as in the rectal system; but this was later replaced by a chamber designed by Professor Dunlap, which was more convenient and worked as well. This chamber, with its connections, is shown very diagrammatically in Fig. 3, in which A represents in cross section a hollow flat cylindrical chamber of brass, with one base led into by a brass tube (B) and the other base open, but closed over by a round membrane of thin rubber dam (C). D is a thistle-shaped glass funnel. D and C are held fast against the flat rim of the brass cylinder by a ring of brass screwed to the latter, with a ring of spongy rubber between the brass ring and the rim of the funnel. E is a brass rod for mounting the chamber. The connections are in principle exactly like those of the intermediate chamber of the rectal system, it being noted that the air space A-C corresponds to the air space within the balloon in the latter, and the air space within the funnel to that inside the bottle but outside of the balloon. When the stomach or duodenal balloon (F) is inflated thru L, the membrane, C, will bulge out into the funnel. The recording device in this case is a U-tube water manometer (G) (diam. 2 cm., length of arms 35 cm.) with a float recorder (cork float, H, aluminum strip, I, kodak-film writing point, J, cork, K, with celluloid guiding strip). By

virtue of the open passage, M, the manometer starts recording in its atmospheric equilibrium position (height of water in both columns equal), unaffected by the inflation of the system F-C. Then, with M closed, increased pressure on F bulges C further into the glass funnel, increasing the pressure in C-G, and forcing the float recorder upward. Decreased pressure on F decreases the bulge of C and the pressure in C-G, drawing the recorder downward.

The recording tambour, being much more sensitive than the manometer, is used in the rectal system, because the rectum is much less affected than stomach and duodenum by respiratory and other changes in intra-abdominal pressure.

It seemed advisable to start each experiment with the pressure in each balloon at some standard value. For this purpose a small water manometer was inserted between the balloon and the intermediate pressure chamber. One manometer was made to suffice for both rectal and stomach systems, by means of the system of connections diagrammed in Fig. 4. By means of the two pinch-cocks, $P_S$ and $P_R$, the manometer may be connected with either the gastric or the rectal system, or closed off from both. In the figure it is shown connected with the rectal system. The usual procedure was to connect the manometer with the system that was being inflated, and to shut it off from both systems during the experiment. The standard pressures used were 100 mm. of water for the stomach or duodenal balloon, 120 for the rectal. They were decided upon partly arbitrarily, partly empirically, by determining the least pressure that showed a satisfactory sensitivity.

The kymograph used for all the recording was the long paper kymograph of the Harvard Apparatus Company. The width of the smoked paper was 20 cm., its length about 235 cm., and the speed used about

6.7 cm. per minute - the whole revolution in about 35 minutes.

The chest pneumograph was a flat, air-tight, rectangular bag of thick rubber 6 x 16 cm. when collapsed. Air passage into the bag was secured by means of a tire patch and a 4.5 mm. thick metal tube inserted therein. To the tube was attached a meter length of 5 mm. rubber tubing. A semi-diagrammatic sketch of this arrangement is shown in Figure 5. The bag is sewed into a strip of bandage long enough to tie around the chest. When the bag is lightly inflated, it is connected by the rubber tubing to a recording tambour (same type as used in rectal balloon system - A.H.Thomas Co. #8047). With the bag tied tightly about the thorax, *increase of girth* (in *inspiration*) causes increased pressure within the rubber bag and a *rise of the writing lever* of the recording tambour. Decrease of girth has the opposite effect. The bandage must, of course, hold the bag under considerable pressure to start with.

The pneumograph for the abdomen was of the Marey type. This is fastened by a tight cord passed around the abdomen, and *increase of girth* (in *inspiration*) occasions the pulling outward of a tambour membrane, bringing about decrease of pressure in tambour and recording system (long rubber tube and another recording tambour), and a *fall of the writing lever*. *Decrease of girth* occasions compression of pneumograph tambour and *a rise of the writing lever*.

Three recording signal magnets (Harvard Apparatus Company) are used. To one is connected the key with which the experimenter signals the presenting of a stimulus; to the second, the key with which the subject signals the experiencing of an emotion (introspective signal); and to the third is connected a Porter Electrical Clock (Harvard App. Co.), signalling 5 sec. intervals in these experiments.

The whole set-up (minus batteries, wires, and keys) is shown in the photograph reproduced in Fig. 6. The two intermediate chambers and the measuring manometer are supported by one vertical rod and the recording apparatus by another, with both rods clamped to the table top. The order of the recording points from top to bottom is:

1. Introspective signal marker
2. Time marker
3. Rectum recording tambour
4. Abdominal " "
5. Chest " "
6. Stomach float recorder
7. Stimulus signal marker

The abdominal pneumograph is shown at the extreme left of the table-top, the two balloons at the right, the thoracic pneumograph in the center, draped over a clamp. The measuring manometer is arranged to show the pressure in the rectal balloon. The writing point of the float recorder is held against the drum by a horsehair and weight suspended from the horizontal bar above all the recording apparatus.

In addition there was the apparatus used to record continuously the course of arterial blood pressure. The first method used was that of Erlanger (6), and makes use of the regular Erlanger blood pressure apparatus. The attached sphygmograph tambour and writing lever were, however, replaced by a separate smaller and more sensitive tambour with double lever recorder, which was mounted with the other recording apparatus and connected with the main body of the Erlanger system by a long piece of rubber tubing. This continuous method of Erlanger is carried out as follows: The pressure in the

arm cuff is kept constant at a level considerably below systolic, so that at every pulse beat some blood is forced thru the cuff. The passage of blood is marked by a separation of the two arms of the pulse curve (Figure 7,a), the presence of the blood under the cuff keeping up the pressure on the air bag longer than when the blood is not present. If the systolic pressure rises, more blood is sent under and thru the cuff, and the top of the separation rises (Figure 7,b). Correspondingly, with a fall in pressure, less blood is forced thru, and the position of the lump falls (Fig. 7,c). This method is expected to show only changes in pressure level and not to give the actual levels.

The second method was that of Kolls, and makes use of the system of apparatus described by him (7). In this method, by means of an ingenious electromagnetic valve, the pressure in a compression cuff is kept at all times at (or very near) the pressure level within the artery compressed, and this pressure is recorded directly by the float recorder of a mercury manometer. A direct curve of the variations in pressure is thus expected to be obtained. With both methods the blood pressure curve was recorded between the rectal and abdominal records.

## 2. The Role of the Reactor.

The reactors or subjects that figure in the final results were ten in number. Seven of these were medical students, two were doctors on the hospital staff, and one was an experienced teacher and worker in psychology - six men and four women. In the case of the women, rectal records were not taken. All the reactors are represented in the final results by twenty-eight experiments.

The first procedure was the swallowing of the gastric or duodenal balloon. About half the subjects have considerable difficulty in this. There are two difficulties in the swallowing: the gag reflex and nausea (with or without vomiting); and these may occur separately or together. Only two of those who tried the swallowing (eighteen in all) finally failed, several carrying on to success after considerable discomfort and even vomiting. For those who have great difficulty the first time, the task is likely to become with repetition more and more uncomfortable and difficult, because of nervous apprehension; while for those who have less initial trouble, the difficulty becomes less and less. There seem to be considerable individual differences in sensitivity and intensity of gag reflex and nausea reaction, not to mention differences in determination. Considering, then, the danger of nausea and vomiting, it would seem advisable to attempt the swallowing at first on an empty stomach. But with the empty stomach are associated the hunger contractions and tone changes, in both stomach and duodenum, which seemed likely to interfere with the clarity of results. Therefore a reactor's first attempt was made within an hour after a medium light meal, and the more successful reactors usually came to do the swallowing about a half hour after a normal meal (breakfast or lunch).

The simplest method for introducing the stomach balloon was quite easy for the more fortunate subjects ( and for the experimenter, too). After tube and balloon were thoroughly cleaned with alcohol and with water, all air was sucked out of the balloon, and the tube clamped off, the bulk thus made a minimum. Then the metal bulb was treated like a large pill and pushed as far over the back

of the tongue as it would go without causing gagging. The attempt was then made to swallow it and the balloon and rubber tube, with the aid of several swallows of cold water (cf. Carlson (8)). Deep breathing was found to come materially to the aid of determination in suppressing the gag reflex. For those who found it impossible to swallow the tube in this simple fashion, the use of a straightened steel wire ( guage #10) was introduced. With this shoved up the entire length of the tube (with care that it be firmly anchored against the blind end of the bulb), the tube was stiff enough for the subject to push the bulb quickly past the gag area. The wire is then most easily withdrawn before much of the tube is fed in, there being thus less friction. In one case extreme cooling of the balloon and tube was resorted to in addition to the wiring, in order partially to anesthetize the gag area.

The discomfort due to the tube when in place seemed to vary directly with the discomfort experienced in the swallowing. Some reactors preferred to keep the tube at the side of throat and mouth; others found a middle position least uncomfortable. For some the discomfort practically disappeared; others were continually and uncomfortably aware of the tube in the throat.

After the tube is swallowed, it is shoved in gradually to the required position. The orientation is accomplished with the Rehfuss tube with the aid of permanent markings thereon. About 3[illegible] cm. from attachment of tube to bulb is located a single line encircling the tube. When this single line is at the lips, the bulb has just entered the stomach thru the cardiac sphincter, in a person of average size. Sixteen centimeters further on are a pair of lines, and after the same

distance again, three encircling lines are found. With the double mark at the lips, the bulb is located in the antrum or beginning of the pyloric (lower) part of the stomach, and with the three-lined mark in position, enough of the tube has been taken in to reach well past the pyloric sphincter, into the duodenum (first part of the small intestine), if the bulb has managed to pass thru. Accordingly, in stomach work the tube is taken in finally up to an inch or so beyond the double mark, to make sure that all of the balloon is within the stomach. If the upper part of the balloon remains in the esophagus, the distention produces in the latter irregular contractions, which are easily distinguishable in the record from the much more regular tone changes of the stomach (cf Carlson (5) p. 75). And if much of the balloon remains above the diaphragm, an inverted respiratory curve will be obtained which will look decidedly wrong. Indeed, the orientation in the stomach is not difficult to attain. In duodenal work, the tube must be taken in finally to several inches beyond the triple mark. The duodenal position, however, is quite difficult to attain, as will become clear in what follows.

The simplest method for passing the bulb and balloon on from stomach to duodenum is the one used in the hospital gastro-intestinal department for passing the duodenal bulb. After the bulb has been taken into the stomach, with the double mark on the tube about at the lips, the subject lies down on a couch on his right side, with his head preferably not elevated; for the pylorus empties into the duodenum toward the right and a little upward and backward, and the aid of gravity is to be used to direct the metal bulb to the pyloric sphincter. The subject feeds the tube in at a very slow rate, so that the distance from the double to the triple

mark (16 cm.) is covered in at least twenty minutes. If this precaution is not observed, the tube is likely to kink up or even double back on itself, and then will not reach the pyloric sphincter. A further wait of ten to twenty minutes is then necessary to give the bulb time to pass into the duodenum in the course of the normal gastro-intestinal movements, the tube being fed in two or three inches further during this time. The sure check upon whether bulb and balloon have reached the duodenum is fluoroscopic examination, tho besides that the tone changes seen in a duodenal record are much faster and more irregular than those of the stomach. After the "incubation" period, then, of thirty to forty minutes, the reactor was taken to the X-ray department and examined with the fluoroscope, in the standing position. The rubber tube and especially the metal bulb are more opaque to the X-rays than the body tissues and therefore cast recognizable shadows on the fluoroscopic screen, and it is fairly easy then to determine whether bulb and tube have passed into the duodenum. If the configuration of the tube appears as in Fig. 8(a), the position of the balloon is satisfactory: the tube hugs the lesser curvature (l.c.) of the stomach and passes thru the pylorus (p.), and the bulb is well within the duodenum. In (b), (c), and (d), however, are pictured unsatisfactory configurations. In (b) the bulb is stopped by the pyloric sphincter (at p), and the tube is forced to follow the greater curvature (g.c.). In (c) and (d) doubling back and kinking have taken up the length of the tube, and the bulb has had no chance to reach the duodenum. This determination from configuration can be made when the actual outlines of the stomach and intestines are not distinguishable. The character of the record of tone changes, as mentioned above, is always a further check. If the tube has not passed into the duodenum, the subject

must undergo a further twenty to thirty minute "incubation" period lying upon his right side; and if a kink appears to boot, the tube must first be withdrawn until it is seen thru the fluoroscope to be straight. It must then be slowly refed during the half-hour period, at the end of which, of course, another fluoroscopic examination is necessary.

With this method, according to the physicians of the gastro-intestinal department, the bulb will pass from stomach to duodenum in from five minutes to twelve hours - not an encouraging prospect. That is usually on an empty stomach. At the start of the work, the experimenter tried the duodenal passage on himself, at first swallowing the tube on a practically empty stomach, about an hour after a very light breakfast (coffee and a piece of toast). The very first attempt was successful after "incubation" of an hour, a member of the hospital X-ray department passing favorably on the position of the bulb, and the subsequent kymographic record showing the rapid irregular tone changes that differ so materially from the tonus rhythms in the stomach. However, three or four subsequent attempts failed completely, tho each time two or three "incubations" and examinations were undergone.

As it seemed likely that the bulb would pass the pyloric sphincter most easily under the influence of the normal gastro-intestinal movements, the variation was tried of swallowing the tube as soon as possible (about a half hour) after a normal, medium heavy breakfast, in the hope that the bulb would pass into the duodenum literally along with the gastrically digested food. After one or two failures with this method, success was uniformly attained in four or five attempts in succession, the last few of these with the surprisingly short "incubation" time of twenty minutes.

It should be noted, of course, that by this time the experimenter had become thoroly accustomed to swallowing the tube and keeping it in place, so that it no longer gave the least discomfort. The final success, it may be ventured, was due not only to the presence of food in the stomach, but also to the absence of discomfort and worry. (Worry about the outcome became less as the procedure became more routine and habitual. Besides, during the later attempts the practice was to read an interesting magazine while waiting for the duodenal passage. For that discomfort and anxious emotions are associated with diminution or cessation of gastro-intestinal movements and with constriction of the intestinal sphincters, is clearly indicated by the observations of Cannon mentioned in the introduction, and by the fact that action of the sympathetic division produces contraction of the sphincter musculature (cf. Gaskell (9), pp. 72 and 152).

With the encouragement of this considerable preliminary success with the duodenal passage, the same technique was tried with five or six subjects. Two of these had so much discomfort that it was considered inadvisable to continue the attempt after initial failure. Two others, however, were so little troubled or discomforted by the swallowing and retention of the tube that about five intensive attempts were made with each of them, each attempt involving around three "incubation" periods and fluoroscopic examinations. Only one of these attempts proved successful, but not until several hours had passed since the meal, so that the hunger changes in the duodenum interfered considerably with the clarity of the record obtained. Of no avail was the use of small amounts of bicarbonate of soda or milk of magnesia in the attempt to cause

relaxation of the pyloric sphincter. More radical drugs were avoided on account of their probable effects on the tone changes under investigation.

Three possible reasons may be suggested for the failure with the reactors as contrasted with the experimenter's success with himself in the passage of the duodenal balloon. In the first place, a reactor's emotional condition in such an attempt is likely not to be as favorable as the experimenter's: it is the latter's own experiment, and he is buoyed up by hope and interest. Secondly, the reactors, after the initial failures, continually showed great concern as to whether the balloon had reached the duodenum: the experimenter, strangely enough, took the matter much more philosophically. Lastly, the reactor's reading matter consisted of medical text books and lecture notes, instead of the experimenter's magazine.

Other methods were tried, involving the shoving of the tube by means of an inserted steel wire; but these also failed. Therefore, the attempt to explore emotional changes of tone in the duodenum was abandoned, and attention was focussed rather on stomach and rectum, which promised a quicker and more economical return. The duodenal technique has been discussed at such length, however, because in further work on the general problem of gastro-intestinal changes in emotions, work that seems now necessary and important, the duodenum should not be neglected. The success in the case of the experimenter himself indicates that the duodenum is far from impossible of access to the balloon technique. Emphasis should be placed in future work upon habituation of the subject to the tube, upon the close relation to the previous meal and consequent utilization of the natural gastro-

intestinal movements, and finally upon the general comfort and pleasant emotional condition of the subject during the attempt at duodenal passage. Annoying techniques such as the use of sodium bicarbonate, the frequent sipping of water, artificial deep breathing, bumping up and down, which were used as possible aids - these should be avoided; and on the other hand, interesting, pleasant reading seems desirable.

After the balloon is in the required position in stomach or duodenum, the reactor lies flat on his back on a couch with a raised head end. This head end of the couch is directly in front of the right half of the apparatus table, and the couch extends forward perpendicular to the front of the table. With this arrangement, the reactor does not see any of the apparatus, and his head is close to the points of attachment of gastric and rectal tubes. The couch is covered with a blanket, and a pillow is provided for the subject's head, unless he prefers not to have one.

The rectal balloon is now inserted. First the air is withdrawn from it and the rubber tube clamped off. The balloon-covered end of the metal tube is then liberally vaselined, and finally inserted by the subject himself as far up the rectum as it will go without painful discomfort. Usually it is inserted as far as the pulley-wheel hilt shown in the photograph of Fig. 6, so that the balloon is well within the anal sphincters. The rubber tubing is directed toward the front of the reactor and then upward toward the apparatus table, passing out under trouser belt. Slight discomfort is felt from the presence of the stiff tube in the rectum, but practically disappears with habituation and adaptation.

The clamps are now removed from the free ends of the gastric

and rectal tubes, and these ends are attached to the recording apparatus. The points of attachment can be seen in Fig. 6. Each consists of a metal junction piece that comes with the Rehfuss duodenal tube. This metal piece permits the joining of a thinner tube to a thicker one. The balloons are not yet inflated.

Next, the pneumographs, already in connection with their recording tambours, are attached to the reactor, the one (already properly inflated) tied about the chest by means of its attached length of bandage, the other tied to the abdomen by means of an encircling long shoe lace. If the blood pressure record is to be taken, the cuff (single or double) is attached to the left upper arm (away from the experimenter), but not inflated until just when the record is wanted; for the pressure of the cuff causes much discomfort as time passes, and must not be continued longer than about ten minutes.

Finally, in the later experiments with the rectum, the subject's legs were tied down rather firmly to the couch, just above the knees, to prevent leg movements that might affect the rectal record, according to a control experiment that had been carried out. One reactor found that a pillow placed under the thighs made this procedure not uncomfortable.

Now the balloons are inflated to the required pressure — 100 cm. of water for the stomach, 120 cm. for the rectum. In some experiments greater pressure was needed for one or both of the systems. In the case of the stomach this was probably due to presence of food or an unusually contracted state.in the rectum to the hampering presence of fecal material. The best procedure for the

rectum, then, would have been to require an enema before the experiment (suggested by E. Weber (10), p.123). But the experimenter felt that the reactors had enough irksomeness in connection with the experiments without the addition of that requirement. He now considers its omission to have been a tactical mistake.

If the introspective signal is to be used, its contact key is placed conveniently in the subject's right hand, and he is instructed to press and release it when he feels an emotion, or, in the adrenin experiments, when he feels anything out of the ordinary. He is always instructed to keep his eyes open, not to move, and to talk only when some change is necessary for his physical comfort.

At the end of the experiment, the reactor is freed from the pneumographs, blood pressure cuffs, the connections with the recording apparatus, and any other hampering attachments. The rectal tube is removed, and finally the stomach balloon is withdrawn. In some cases painful difficulty is experienced in this last procedure on account of constriction of the cardiac sphincter. This is overcome by swallowing first and then pulling the tube out rapidly, allowing just sufficient time for the swallow to produce relaxation of the sphincter. The tube should be pulled out rapidly in order not to leave time for the bulb to set up additional swallowing reflexes.

### 3. The Running and Recording of the Experiment.

The experiment takes place in an 8 x 16 foot room that can be completely darkened and is almost sound-proof. The apparatus table is in one corner of the room, with its back against

the end wall, the right side of it (looking at Fig. 6) against the side wall. The subject's couch thus runs along the side wall (with a foot or so intervening for the sake of the blood pressure adjustments); and the experimenter works at the subject's right, or toward the left of the table, looking at Fig. 6.

After the reactor has been completely arranged and instructed, the experimenter can turn his attention first to the writing levers and kymograph, then to the actual stimulation. The writing points should be placed against the smoked paper before the arrangement of the reactor, and the time clock should have been started that early, too, to allow plenty of time for its proper adjustment. The tambour levers are now given their final zero positions ( any later adjustment must be recorded as such on the smoked paper); the abdominal pneumograph is thrown into action by the lowering of the clutch bar (shown raised in Fig. 6); the atmospheric opening between intermediate chamber and recording device in stomach system and in rectal system is closed, starting the recording of those systems. The kymograph is set going, the pressure of the writing points on the drum is finally adjusted in very short drum space, and then, if necessary, the blood pressure recording is started and adjusted. A short control record is taken before stimulation begins.

Besides the kymograph, the recording note-book plays an important role. In it are written all the stimulating procedures in detail, as planned before the start of the experiment. Every major act of the experimenter that might serve as an emotional stimulus must be written in the note-book in advance, and the experiment then run in accordance with the plan in the note-

book, which is kept within reach at all times. Of course, foresight sometimes fails, or for some other reason the order of procedure is changed. Then the variation in procedure must be entered in the note-book in its proper position as soon as it occurs or is foreseen. A portion of the plan of an experiment is here appended as an example:

1. Light - Door closed
   Light off - Wondering why, expectant, not apprehensive.
   Light on.

2. Water - just stiff (resistant), not surprised, saw coming.

3. Pistol - Light off - Thought most happen in dark, didn't affect.
   Shot - startle for a moment (assume composure)
   Light on

Under the first stimulus (1.Light) there are three procedures -- first, closing the door, then turning the light off, then turning it on. Under the second there is but one (throwing cold water suddenly in the reactor's face), and under the third, three again. With the performing of each of these constituent acts, the experimenter presses and releases the stimulus key, making a vertical mark on the kymograph paper with the lowest signal magnet. The numbers 1, 2, 3, etc. of the main stimuli (light, water, pistol in the above) are marked on the drum with a pencil point under the writing points just before the procedures in each case begin. Then, in the experiment used as illustration, after the number"1" on the kymograph record there must appear three stimulus marks, after "2" one mark, and after "3" three marks. Then the orientation is unmistakable.

In the note-book is entered the time and approximate size (small, medium or large) of the reactor's previous meal (breakfast

or lunch). The time of beginning and end of the experiment was more usually written directly on the kymograph paper. After the end of the experiment, when the reactor was freed of all encumbrances, including balloons, he was asked to report what his reactions had been to the various stimuli and important constituent procedures. The retrospective introspective data thus obtained was entered in the note-book next to the corresponding stimuli. In the example given above, the introspections are entered as they appeared in the note-book. The different procedures were gone over in order, and the subject was questioned on each important one. In the example, the reactor was interrogated somewhat as follows:

"At the very beginning, what effect did the closing of the door have on you, just before turning off the light?"

The answer may have been: "I didn't notice it", or "I don't remember", or "That didn't bother me"— not significant enough to enter.

Then: "How did you feel when the light was turned off that first time?"

The answer is recorded in its essentials.

Probably no question was asked about the turning on of the light. And so forth.

If the introspective signal was used, the signals were numbered in the note-book at the end of the record, and the reactor was asked to account for each signal mark, being told which stimulating procedure the signals were associated with. The data thus procured was of course entered in the book in connection with the signal numbers.

The smoothest procedure was obtained when all the stimulation material was placed in advance close at hand, though properly concealed from the reactor. Then, especially in the later experiment, when the procedures had become standardized and routine for the experimenter, the whole experiment, involving ten to twelve major stimuli, could be run off without stopping and restarting of the kymograph. This, of course, could not be done when blood pressure was being recorded on account of the necessary rests for the subject's arm.

After the reactor has been dismissed, the kymograph record must be prepared for preservation. First, simultaneous ordinates are marked on the record. The position of kymograph stand and of the recording apparatus must not be disturbed until after this is done. The drum is rotated until the writing point of the stimulus (or introspective) signal magnet is at one of the vertical stimulus (or introspective) signal marks. With the drum stationary in this position, a clear vertical mark is made with each of the recording points, extending thru its own record. This mark, or ordinate, shows at just what point in the record the stimulus (or introspection) in question occurred. In the case of the respiratory tambours, the ordinate was made by simply moving the writing lever up and down with the finger; with the float recorder the mark was made by blowing into the atmospheric opening between intermediate chamber and manometer. Ordinates are applied for all the recording levers for every stimulus and introspective signal mark, and while the paper is being rotated for the application of simultaneous ordinates, each writing point traces a horizontal line which will prove

useful later in studying the changes in levels of the records. For the convenient location of these horizontal lines close to their respective records, vertical adjustment of the writing levers is possible without disturbance of the horizontal alignment that is so important for the simultaneous ordinates.

After all the ordinates are marked, the kymograph is pushed away from the writing points, and the smoked paper record is carefully removed and cut into two sections for easier handling. Then all the data that appear in the note book are transferred directly to the smoked record in the proper places thereon, so that every stimulus (or introspective) mark is labeled with the procedure (or introspection) it denotes, and the retrospective introspections are entered in connection with their respective stimuli. All other data about meals and times and what-not are transferred to the smoked record, so that the latter is the complete record. It is then shellacked and preserved.

## 4. The Stimulation

To arrange experimental emotional stimuli is not an easy matter. Stimuli in an experimental setting are much less effective emotionally than those the reactor meets with in his various life-situations. For the most part the reactors tend to accept at least philosophically, if not cheerfully, whatever comes along. They know that nothing really injurious will happen to them, and on the other hand nothing of a very pleasant nature can take place in an experimental setting. This foreknowledge leads often to a doubting attitude that still further defeats the experimenter's aim. Two or three times it has happened in the experiment that the subject when confronted and even touched by a real snake, was certain that it was

not a snake but a piece of rubber tubing. The subjects do not expect anything drastic, but do expect that the experimenter will try to fool them into thinking some innocent stimulus drastic. With this danger in mind, the best policy is not to attempt to deceive the reactors, but from the start to present straightforward and unmistakable stimuli. If some convincing deception seems an effective and desirable stimulus, as in the case of the electric shock procedures that will be described, it would be best to postpone it to the very end, when it is certain that the experimenter will not work any more with the same reactor. Also, great pains should be taken to make the deception truly convincing, and there should be as little chance as possible of the reactor's finding it out subsequently (as he does in the time falsifications).

For the effectiveness of nearly all stimuli, of course, the exaction of a friendly pledge of secrecy from the reactors is desirable, so that future reactors will come to the experiment without knowing anything about them.

With the use of the stimuli that were finally retained and standardized, the emotional reactions, major and minor, in the following list were reported by the reactors:

Fear - from mild apprehension and worry to terror

Startle

Surprise

Amusement (in connection with planned stimuli, incidental ones, and the reading of letters)

Disgust

Shame (in connection with an incidental stimulus)

Relief

Tenseness

Pleasantness

Unpleasantness

Wondering

Resistant feeling

Admiration

Envy — (in connection with the reading of letters)

Delight

For the most part these reactions were necessarily mild. The emotional effect in the laboratory of even the physical contact of a snake, that the subject knows is harmless, cannot compare in magnitude with the effect of a burglar entering the bathroom window.

Before the detailed discussion of the stimuli that were finally adhered to, it may be of value to mention some of those that were tried and rejected. One group of stimuli that involved deception was rejected when it became clear that homesty was the best policy. These included such falsifications as regretfully telling a reactor that he had been kept so long as to be late for an appointment which the experimenter had learned about before the experiment. This sort of time falsification was readily believed, but would have a bad effect on the experimental morale. Then there was the trick of breaking over the forehead of the reactor an egg that had previously been "blown" and filled with cold water. The deception was usually detected at once, and even when not, the emotion experienced was amusement instead of the anger aimed at. The absence of anger among the emotions reported should be noted. This is due partly to the philosophical experimental attitude of the subjects, partly to the impossibility of using any

really drastic stimulus. It is possible that if a real egg had been used (a perfectly feasible and harmless, if messy, procedure), some of the subjects might have been slightly angered. This might be worth while trying. At any rate, the false egg breaking was replaced by the straightforward dashing of cold water into the reactor's face. It might be possible, however, to get a reaction of anger from a reactor with some keen "complex" or prejudice - for instance, by a remark about negroes to a typical southerner, or by an appropriate remark to a present-day rabid French partisan. In such cases, with real anger, it would be difficult to restrain the subject from talking, with its deleterious effect on the record thru respiratory irregularities.

A group of stimuli involving physical pain was also rejected. The prick of a sharp stylus and the electric shock from an inductorium were tried, but did not seem to give real emotional reactions, or at any rate emotional reactions intense enough for the purpose or method. The subjects reported local pain but no emotional effects, and the tonus records were uniformly negative. It may be that pain stimuli must come closer to the injurious level to cause real emotion, or to have the effects on the sympathetic system that have been physiologically demonstrated.

Some olfactory and gustatory stimuli were rejected for similar reasons. In the hope of eliciting the disgust reaction, some chemical substances were tried - valerianic and butyric acids and butyl mercaptan; but their odors were neither strong enough nor disgusting enough to produce the required effect, and more organic odors derived from living material, were resorted to, as will be mentioned below. The taste of oyster and sugar also proved not to be

intensely enough disgusting, and besides, it was inconvenient to apply.

Lastly, the attempt to cause amusement by the telling of jokes was abandoned. It seemed difficult to pick out a "sure-fire" story, and if the joke did take, the resulting laughter caused too much respiratory irregularity and consequent unclearness of the record. However, the experimenter is still of the opinion that the joke stimulus might be made to work.

We come now to the discussion of the stimuli that were continuedly used, with some success.

1. Turning off the light. -This was usually the first stimulus, after the preliminary control period. The door of the chamber, open at the start, is closed and the procedure signalled (cf. example of note-book record, p. ~~35~~ 23 ). A single electric light, close to where the experimenter is standing, is left burning. As the chamber, fitted up as a dark room, has no window, turning off of this light leaves the room in total darkness. As the experimenter reaches up with his left hand and switches off the light, he of course signals with his right hand. The light remains off for about twenty-five seconds, E (the experimenter) counting five clicks of the time signal; then E switches the light on, signalling. The turning off of the light has caused reported reactions varying from wondering or expectancy or tenseness to apprehension.

2. Pistol shot. - Often the second stimulus presented. The door still closed, E turns out the light again, as above (always signalling). He then quietly takes up the pistol (starter's pistol, with blank cartridge in position), which has lain hidden near by, and, pointing it upward usually, so that R (the reactor)

can see the flash, after about half a minute (not standardized) fires it (signal). Light then is turned on (signal). In this group of procedures, the turning off of the light has elicited reported reactions similar to those under procedure 1, tending however to be of less intensity. The unexpected firing of the pistol has always caused startle, fright being reported but once (presumably startle plus fear). Pistol is held in right hand, signal key pressed with left.

3. Pistol threats, with unexpected shot. - This was one of the later procedures, about the 7th, 8th, or 9th. Before the experiment, the weapon is loaded with two blank cartridges, with two empty chambers between them. The first is shot off in procedure 2. Then in this procedure, carried out in the light, the pistol is placed in position (signal) near the subject's head, in plain view, and held there 5 to 15 seconds. This usually calls forth some nervousness or apprehension. Now the pistol is jerked away suddenly, pointed at the floor, and the trigger pressed (signal), making a loud click (the first empty chamber is under the hammer). (click sometimes produces startle, sometimes amusement, sometimes no effect). E. acts somewhat embarrassed and annoyed, examines the pistol, then places it again in position (signal). Usually this produces apprehension again, sometimes in greater degree because there is less doubt that the pistol will be fired. After the short wait, the click again occurs (signal), E withdraws the pistol in a satisfied manner, and says, "I just wanted to get your anticipatory reaction"; and in finishing the lasttword, fires the second cartridge, and signals (surprise and startle). The reactor seems to take this group of procedures not

as an attempt to fool him (as in the falsifications of time, etc.) but as an efficient way of getting several kinds of reactions - with one subject the startle was followed by appreciation of the procedure.

4. Dashing of water into R's face - the second or third stimulus usually. Before the experiment a tumbler is "planted" behind the kymograph, containing a small amount of cold water. During the experiment,E. grasps the tumbler suddenly with his right hand, with a motion that he tries to keep hidden from R. He immediately dashes the water into R's face (aim must be careful), signalling with his left hand. This stimulus caused for the most part only surprise or startle. It was seldom minded. On one of the latter occasions the reactor had a rather unpleasant emotional reaction, because he was wearing his only clean collar and shirt.

The following three stimuli are the odors that finally proved successful in eliciting reactions of disgust. Tho some subjects claimed to be practically unaffected by the odors, medical students being well accustomed to such things, in some reactors disgust was produced, attaining in a few cases a high degree.

5. Decayed rat flesh. - A small piece of a dead (or operated) laboratory rat was placed in a test-tube, corked, and allowed to decay. The test-tube, with the two others of 6 and 7 below, is placed before the experimenter on the table behind the kymograph. At the proper time E brings out the tube, uncorks it, and places the open end directly under R's nostrils (signal). After 10 or 15 seconds E. announces: "This is a piece of rat flesh, allowed to decay." (signal). The nature of the odor makes the announcement

plausible, and the latter sometimes intensifies the disgust. After another 10-15 sec. delay, E., with shaky hand, allows end of tube to touch R's nose (signal). This procedure was discovered thru accident to be effective in increasing the disgust. It is repeated after another short delay. (The order of touchings and announcement is varied for the different odor stimuli). After a further delay of a fraction of a minute, the tube is withdrawn (signal).

6. Urine
7. Feces
} Specimens of these were procured from the clinical laboratory and also kept in corked test tubes. They are administered just as 5 is, the announcement being: "You probably recognize urine", or "I got the feces from the clinical lab.", or (when the urine was stale) "I got this downstairs about a month ago", or the like. These three odor stimuli were distributed judiciously among the other stimuli.

8. Rat - Presented usually 4th or 5th, sometimes 1st or 2nd. One of the laboratory white rats ( a tame black one would be better), always a large, old one, was used. The rat was not "planted" in the experiment room, as it did not seem easy to hide it in a cage inconspicuously, but was left in its cage a few rooms away. In running this procedure, E. signals and leaves the experiment chamber. He is gone about a minute getting the rat, which he brings back in the left pocket of his laboratory coat, on the side removed from R. He signals when he enters, then after about 10-15 sec. brings rat out and places it on R's face (signal). It remains there, usually crawling a bit, for 10 to 15 seconds, then is removed (signal) and returned to its cage, E. signalling when leaving and entering the chamber. The reaction, if any, is usually

an unpleasant feeling due to the sharp claws, and a slight disgust reaction due to olfactory stimulation.

9. Snake. - Usually presented near the middle of the experiment. - Three kinds of snakes were used: two water snakes about 2 1/2 feet long and 3/4 inches in diameter, a small King snake about the same size, and a larger King snake something over 3 feet long and an inch or so in diameter. These were all quite harmless snakes. The water snakes were the easier to keep; because it was easier to procure minnows, tadpoles, or even gold fish to feed to them than to obtain mice for the King snakes.

The snakes are best handled by grabbing the neck suddenly and firmly with one hand, and then the tail with the other. In the cool weather of the winter and early spring, no trouble at all was experienced in handling the snakes; but in warmer weather they were no longer sluggish and objected strenuously to being caught. Under these circumstances the experimenter was bitten not infrequently; but the bites were hardly more thanscratches, were not painful, and had no bad effects. This trouble was finally avoided by the wearing of old thick leather gloves. In no case did the snake attempt to bite the subject, confining its attacks to those alone who tried to handle it.

The simplest procedure in preparing for the snake stimulus, used uniformly in the later experiments, was to place the snake before the experiment in a closed but air-holed cardboard box about 12 x 9 x 2 inches, and to "plant" the box in an inconspicuous place in the experiment chamber. But in view of the difficulty offered in some of the early experiments by the reactor's doubt of the snake's reality, a variant on the simple method was sometimes used, by which the subject

was first acquainted with the snake. The snake was placed, before the arrival of the reactor, in a glass jar (closed, but with air supply) where the reactor would see it on coming to the laboratory. Sometimes there would ensue short conversation about the snake, the reactor showing interest and curiosity, and the experimenter answering with some cock-and-bull story of how Dr. So-and-so was studying its behavior — it wasn't thot to be dangerous, at least it wasn't poisonous. The snake was later smuggled into the experiment chamber in the cardboard box, or brought in just before the presentation was to occur. But this procedure was conducive to distrust, and the reactor either was constantly on the lookout for the snake or had learned it was a pretty harmless little thing anyway. So the simpler procedure seemed preferable, and the presentation could with care be managed so as to show pretty clearly that the snake was a really live one.

The presentation of the snake was carried out with the door closed, the closing of the door, when necessary, being signalled as usual. E takes snake from box as rapidly as possible, signalling with the left hand as it passes the table (this signal is known as "on" in the records). The snake is then held in front of the reactor for a few seconda and allowed to writhe so that R can get a convincing view of its nature. It is then placed on R's chest, near the chin. (This position of the snake interfered completely with the action of the chest pneumograph. With another pneumograph of the same type as the abdominal one, this difficulty would not have been encountered. But the attempt was not made to avoid it, because it was early judged that the chest pneumograph was of no importance - see discussion below. The pneumograph was retained, however, to be on the safe side.) This

position seemed a good one because the snake's presence and movements are clearly felt, and the reptile is near enough to the face to cause in most cases fear of injury or disgusting contact there. The subjects who minded the snake at all, uniformly reported that their reactions would have been much more intense if it had touched the face, and therefore it would in future be desirable to try that method of stimulation. In the past apprehension for the subject on the part of the experimenter has usually prevented it. In two cases where the snake did touch neck or face, the reaction was intensified. The reactions reported included disgust and fear - from mild apprehension to ,in one case, terror. After the snake has remained on the reactor for about ten seconds, the light is switched off (signal), to be relit five to ten seconds later (signal). In case where only disgust was felt, the invisibility of the snake has usually decreased the reaction; when fear occurs, the reaction is sometimes increased, sometimes decreased because the snake usually remains very quiet in the dark - in cool weather that is: with warmer temperature it is likely to slip off the couch onto the floor, giving rise to incidental procedures and reactions discussed below. Another approximate ten seconds, after the relighting of the light, the snake is removed (signal) and returned to the cardboard box. Relief is then usually experienced — by both R and E.

There were three cases in which the snake slipped away off the couch, crawling under it. In the last one, E was wearing gloves and did not have very much trouble, R not noticing the chase particularly. In the other two, the snake was not caught without a chase and struggle that left E with a spectacularly bloody but really uninjured right hand. (The scratchy bites were treated with

iodine and then forgotten). The bloody hand was shown to the reactor as additional stimulus, and in both cases caused amusement. In one of the cases, the whole chase and struggle with the snake was highly amusing to the subject, who even reported amusement later in the experiment at the mere thot of the occurrence.

10. Electric Shock. - This stimulus, usually near the later middle in order, was presented with two different methods, both involving deception. In the first method (A, below), the deception was covered up in a majority of cases. In the second method (B), it seemed not to be detected, because of apparent ignorance of the reactors regarding some electrical matters, tho it is hard to believe that they could remain fooled in the end.

A. Threat of shock, with loose connection and fuse explosion. - (General suggestion for apparatus and method from Moore (11).)

Apparatus: In a wooden box 8 inches square and 5 inches high, with open top, are mounted two electric light sockets, each containing an ordinary electric light bulb. Two wires, connected to one throw of a double pole, double throw, kinfe-blade switch, enter the box thru two holes., one on either side of the box, toward the back, and are connected so that current will pass thru both lamps in series. A wooden shelf is mounted with nails on the back of the box, outside, and on the shelf is placed a 3/8 inch thick circular sheet of asbestos 3 inches in diameter, to which has been screwed two binding posts. Two wires connect the latter to the other throw of the double pole, double-throw switch, which is firmly mounted on the left end of the kymograph table, toward the front. A four or five-inch length of very thin electromagnet winding wire, with insulation burned off by a match, connects the two binding

posts together and lies slightly coiled on the asbestos surface between them. Before the experiment a good-sized pile of flash powder is heaped on the abbestos over the coiled fuse wire, and care is taken not to disturb this heap in handling the box. The two middle binding posts of the switch, in connection with the two knife blades, are wired to a plug which can be connected to the regular 110 volt lighting system. With this arrangement, throwing the switch forward lights the lamps in the box, and throwing it backward burns the fuse and explodes the flash powder. To each of two of the mounting screws within the box is connected a long wire, which passes out thru a hole in the front of the box and ends in a roll of sheet zinc, as a shocking handle. These two connections are such as to exclude any passage of current to the handles, and, to aid the deception, one of the connections is broken before the experiment.

Procedure: Before the experiment the box and fuse, with heap of flash-powder, lie underneath the table, with electric light plug unconnected. When the time comes for the "shock" stimulus, the box is brought out and placed on a chair or stool (signal) about four feet to the reactor's right, within his field of view, and the lighting plug is connected to the wall socket. After about 15 seconds' record E closes switch forward (signal) to "try" the lights, which, of course, should flash on. (The usual emotion here is "wondering",) After about 20 seconds E announces: "I want to try a powerful electric shock" (signal). This produces rather extreme degrees of fear in some cases, and usually at least some nervous apprehension. In the most extreme case, discussed fully among results, the reactor remonstrated verbally and was told that only a part of the lighting voltage would be used. This same

"reassurance" was given some of the other reactors, and served, it is believed, not to decrease the fear of the shock but to increase belief in the stimulus. Another 20 seconds later the subject is given the handles to hold, one in each hand (signal) - "keyed-up", or apprehension, or fear reported here. Now E says slowly, "One - two - three", and with "three" throws switch forward, lighting the lamps, and presses signal key, raising switch almost immediately, rather excitedly. The period of holding the handles is one either of apprehension or of "nerving up", an interesting emotional effect which seems to cancel apprehension. The shockless closing of the switch brings relief in almost all cases.

E now turns to R and asks, still excitedly, "Did you feel it?" Upon the answer, "No", he says ,"There must be something wrong", and turns to examine the box. He picks up the loose end of wire, saying, "Loose connection", then stops the kymograph, takes the handles from R, and leaves the room to get a screw-driver. Then the connection is actually repaired. All this time is usually a period of doubt for the subject, but when the kymograph is restarted and the handles are again given to him (signal),he seems to have at least a half belief, with some apprehension. (One subject thot at this time the thing was a fake, several had no doubt of the bona fides. Questions were not asked, however, about this ticklish matter). Again "One - two - three", but this time the switch is thrown backward (signal) and explosion results, startling R. Relief naturally follows, E explaining that the fuse was blown, or making some disparaging remark about home-made fuses. He likes to believe that this saves his reputation — partially anyway.

B. Threat of shock, with real shock from inductorium. — The

same box is used in this method, which was suggested by Professor Ethel Bowman, of Goucher College. The double-throw switch is left connected as before, but the fuse, tho left in place, is not used. An inductorium (Harvard Apparatus Company) is placed behind the box, hidden under the shelf. The wires of the shocking handles are now connected to the secondary of the induction coil, but still pass thru the box via the holes in sides and front. The primary with interrupter is operated by a single dry cell, the wires passing along with those of the lamp circuit. A key is in the primary circuit, situated on the table in front of the double-throw switch, so that it is easy to throw the latter forward, lighting the lights, and operate the induction coil at the same time - this with one hand, signal with the other.

Again the apparatus is under the table before the experiment, unconnected with the lighting current. At the proper time, the wall plug is inserted and the box, with inductorium, is brought out and placed in much the same position as was used in method A, only this time on the floor, the better to hide the inductorium. When the box is in position a signal mark is made. After a fraction of a minute E throws the switch forward to "try out" the lights (signal), opening it again, of course. R is now given the handles (signal) (apprehension), and after 20 to 30 seconds E says: "Within a half minute you will receive a shock of 50 to 75 volts" (signal). After just 1/2 minute by the time signal, E operates lights, inductorium, and signal, continuing the currents of the first two a second or so. The shock is startling, and if of the proper strength, painful as well. The procedure can then be repeated with good emotional effect by E's saying

"Again in half a minute" (signal), and then repeating the shock with lights at the proper time (signal). Finally the handles are taken from the reactor, affording relief. The reactors do not seem to realize that the shock is not generated by the electric lighting system - at least they say nothing about it.

11. Subcutaneous injection of adrenin. - In general this was the last stimulus used. It was given to the reactor in a separate experiment after the stimuli described above had been presented to the same reactor in a preceding experiment or several preceding experiments. The recording of blood pressure was undertaken in connection with this stimulus for the sake of having some independent criterion of the time relations of the effect of the drug. This stimulus seemed a desirable one, apart from the interest in the drug effects, in that it afforded opportunity for emotional reactions before the actual injection. The results of the emotional stimulation due to the procedure, and not the results of the drug injection itself, will figure in this paper.

Preparations: - The adrenin used (other names are epinephrin, adrenalin, suprarenin, suprarenalin) was Armour and Company's Suprarenalin Solution, 1:1000. This can be boiled before using, according to the Company's circular, without deterioration. The solution is used just as it comes, without dilution - 1:1000 being an appropriate strength for subcutaneous injection (cf. Clough (12))). Besides the adrenin, there must be on hand sterile physiological salt solution for control injections, and alcohol and iodine solution for the aseptic precautions. For the latter, sterile gauze strips and sponges are also provided.

The syringe used was a B-D Luer Tuberculin syringe of 1 c.c. content, graduated, of course. This, along with two hypodermic needles, three or four small test-tubes (5 cm. long, 1 cm. in diameter), and a large surgical clamp used to handle syringe, needles, and test-tubes, was boiled for several minutes in distilled water in a sterilizing tray over an alcohol lamp, just before the start of the experiment. A folded strip of sterile gauze lines the bottom of the tray to prevent cracking of syringe or test-tubes. The boiled paraphernalia remain in the covered tray until just when they are required for use.

The tray, with its iron stand and the alcohol lamp, the four bottles of solutions, and the sterile packet of gauze sponges are placed on a small table covered with oil-cloth, and the table is placed behind an inside door of the experiment chamber, hidden from the subject's view.

Procedure: With the kymograph running, E announces, "I am going to try a subcutaneous injection of adrenalin" (signal). Several times the reactor has doubted this. Next, the table is carefully brought out near the subject, in pretty clear view (signal). This usually dispels the doubt and starts worry in the reactor. After a record of a minute or so, the kymograph is stopped, and now the syringe is filled with sterile saline solution, full aseptic precautions being taken. The syringe and a needle are removed from the sterilizing tray and assembled, with the help of the sterile surgical clamp, and then laid carefully on the table. Again by means of the clamp, a test-tube is removed from the tray, held upright on the table, and half filled with saline solution, which is then boiled over the alcohol lamp. The required amount of the solution is drawn from the test tube into the

syringe, which is again laid upon the table. The quantity of saline solution used is always the same as that of adrenin that it is planned to use. This was always 0.5 c.c. (= .5 mg. of adrenin) (cf. Clough(11)) in the first trial with a given subject, and was increased to 0.75 and 1.00 c.c. in any further trials, in connection with which, however, no further control salt injection was deemed necessary.

With the syringe thus in readiness, the kymograph is started, and the experimenter prepares to clean a small area of skin on the reactor's right upper arm, which should be previously bared. A sterile gauze sponge is soaked with alcohol and left on the top of the opened bottle. Another sponge is soaked with iodine and taken over to the reactor, E signalling on the way (known in the records as "Ready to clean arm"). A spot on the subject's arm is cleaned with a rotary motion, the sponge is returned to the opened top of the iodine bottle, and the excess iodine cleaned off the arm with the alcohol (signal: "Arm cleaned"). Then as E approaches R with the syringe, he signals ("Ready to inject"). The skin is pierced, the injection performed, and the needle withdrawn (signal: "Injection completed"). The syringe is replaced upon the table - always in such a way that the needle and the interior of the syringe do not come into contact with table or anything else; and the control record is taken for around 2 to 5 minutes. Then E announces: "I am going to repeat the injection" (signal), and the procedure is practically repeated. That is, about a minute after the announcement of the repetition, the kymograph is stopped, and the syringe is filled, this time with the same amount of suprarenalin solution. The syringe does not need to be resterilized, but a fresh test-tube is taken from the tray, the solution is poured into it and

boiled, and the syringe filled from it and placed again on the table. Again the kymograph is restarted, a fresh place on the arm is cleaned as before, and the injection made, with signals as before.

Various emotional reactions are associated with the injection procedure itself, and there is usually some worry at the first feeling of the physical effects of the adrenin (vascular, for the most part), which start about 45 seconds or a minute after the injection. These effects, however, are to be omitted from the scope of the present paper. Great improvement in the introspective technique would be necessary to give results of any significance.

12. Reading.

A. Subject's personal letters:

In an attempt to make the experimental situation closer to the reactor's life situation, the procedure was tried in two cases (both women students) of taking the record while the reactor read to herself a letter received that day but not previously opened, and in reading signalled with the introspection key, in accordance with instructions, when an emotional effect was felt. The reactor was at a previous session asked to keep for the purpose any letter that should come on the day of the experiment in question, especially one that might prove of emotional import. In the firat case, the only emotion reported was amusement; in the second case, two letters were thus read, and amusement, admiration, delight, surprise, envy, and disappointment were reported. In this last case the introspections for the first letter were reported, with kymograph stopped, between it and the second letter, and those for the second letter right after it. There were nine introspection signal marks for the first letter, six for the second, so that it was quite a task for

the reactor to remember them correctly, especially as she had been instructed not make any great effort at memorizing during the reading, so as to avoid an extraneous emotional effect, but just to remember the order of introspections as best she could naturally. It would be better procedure to take reports after each set of three signal marks.

B. Passage from a book.- In the same experiment in which the two letters were read, the experimenter read aloud to the reactor five selected short passages (9 to 25 lines) from Barbusse's "Under Fire" (E.P.Dutton and Co., New York, Twelfth Printing, Jan. 1918). R was instructed to signal any emotional reactions with the introspection key, and the report was taken right after each passage. With the stimulus key E signalled the start and finish of each passage and also one, two, or three premarked places in each passage that he had picked out previously as probably of special stimulating value.

The passages were as follows:

Page 265, lines 6 to 14 (always inclusive). Signal end of line 10. (Introspection signal and report: Displeasure at the sort of thing being read).

Page 274, lines 15 to 26. Signal after 4th word in line 18, and after the 6th word in line 24. (Introspection: Uninterested, yet disturbed.)

Page 296, lines 7 to 19. Signal after 8th word in line 12, and after 8th word in line 15. (Pity).

Page 297, 12th line from the bottom, to page 296, line 8. Signal after 4th word, 5th line from the bottom, page 297. (Disgust).

Page 301, line 12 to next to last line on the page. Signal after 1st word in line 21, after last word line 27, and after 5th word

5th line from bottom. (Pity).

13. Announcements:-

The first time the rectal technique was to be used with a given reactor, the experiment was started with stomach alone, and then E made some such announcement as: "I should like to try a rectal balloon now as well" (signal), According to the reports, no reactor was emotionally disturbed or affected by this announcement.

If, after the scheduled stimuli had been all presented, there still remained considerable kymograph space, the announcement was made: "There will be no more tricks. I want to get just a normal record now " (signal). This usually caused some relief.

Usually near the very end of the record E announces: "That will be all. Just a minute more " (signal). This, too, usually causes relief.

14. Incidentals. - Most of the incidental actions of the experimenter, planned or unplanned, were signalled and recorded, such as the opening and closing of the door, the experimenter's leaving and entering the chamber, the inflation and deflation of the blood-pressure cuff, and additional instructions or remonstrances to the reactor. For any of these procedures might happen to bring about a considerable emotional reaction in the subject, and if they are signalled, the result would not be lost. For example, the reactor talked during one experiment, in spite of the specific instructions at the start. Before the next procedure, then, E said, "It would be better not to talk", and signalled. R reported feeling ashamed at this remonstrance.

15. Variations. - The procedures described were not the invariable ones used with each particular stimulus, but they were

the procedures finally adopted as standard and considered the most efficient. The order of stimulating activities appears of course in each record in the labelled stimulus signal marks, so that variations from the standard, whether major or minor, are duly recorded.

The order of the various stimuli, which was not invariable, has been roughly indicated in the detailed descriptions. Two or three general principles seem to be involved in the selection of an effective serial order. The two principles of convincingness and of habituation or adaptation both suggest starting with simple, less drastic procedures such as the light and the pistol shot and passing on thru the odors to the more drastic stimuli of the snake and the shock. For the latter are more likely to be believed as real after the simpler straightforward stimuli; and also the simpler stimuli are likely to have more effect before the reactor has become accustomed to the situation and the fundamental harmlessness of the stimuli - that is, before the reactor has become blasé. This order from the simpler to the more complicated is, of course, also much easier for the experimenter. Finally the principle of variety comes into play in distributing the odor stimuli among the other procedures, and in separating the two pistol techniques.

### 5. Difficulties and Limitations.

In this final section of the discussion of method, the writer proposes to summarize and discuss some of the difficulties involved in the methods used, and finally to take up the fundamental limitations of this balloon method and the consequent difficulty in interpretation of the records.

1. Leaks in the pneumatic systems. - Leaks in the various pneumatic systems of the recording apparatus are of course to be

carefully avoided, as it is evident they would interfere essentially with the significance of the records. In making up the apparatus, therefore, new rubber tubing should be used, new balloons, and new sheet rubber for the tambour membranes. The joints between rubber and glass or metal tubing are protected by a layer of shellac, which is spread on the end of the metal or glass tube just before the slipping on of the rubber tubing. In spite of all carefulness and tightness in the tying on of the tambour membranes, the resulting joint nearly always leaks or soon springs a leak in some spot and is therefore also protected by the application of shellac. The tied junction of balloons and tubing is firm enough not to require shellacking. New balloons and tambour membranes are tested after tying (and shellacking in the case of the tambours) by inflation under water, to detect possible leaks in the joints or in the rubber itself. The balloons are also inflated before tying, for the detection of any gross defects. It should be noted that shellac must not come in contact with water until the former has dried completely, for if it does, it will not dry out. The intermediate chambers are also safeguarded by the use of shellac.

In spite, however, of all care in making up the apparatus, leaks are constantly developing because of the perishableness of rubber. The thin rubber of the balloons is the most perishable. Seldom can balloons be used twice. In the stomach they seem to succumb to the gastric acid, in the rectum to the vaseline used. The balloons are always tested immediately before and after an experiment, and the leaks are found more often to develop between experiments, tho sometimes they are sprung during the experiment. The safest procedure would seem to be the use of a new balloon for

each system for each experiment. The thin balloon rubber was found to be much too perishable for convenient use on the recording tambours, and a thin dental rubber dam was substituted, giving much better wear and ample sensitivity. Such membranes lasted about two or three weeks. A considerably thicker rubber dam was used for the tambour of the abdominal pneumograph, and lasted about twice as long. The bag of the chest pneumograph was of still thicker rubber and sprung a leak but once in its seven months of use, being mended with the aid of rubber cement and a strip of rubber. The rubber within the intermediate chambers was much better preserved, being protedted from loss by evaporation of water and other necessary ingredients. The thin balloon in the rectal intermediate chamber had to be changed only once in about six months, and the rubber dam in the new-style gastric chamber (same sort as on the recording tambours) has lasted about the same length of time without developing a leak.

The tubing, too, exposed to the air, wears out, especially at the joints with glass or metal, where it is stretched.

The presence of leaks is easily detected in the records, but to avoid their deleterious presence during actual experimentation, the various systems are tested out on the day preceding each experiment. The bag of the chest pneumograph is compressed under a weight and the tambour of the abdominal one is clamped in a compressed position, the resultant pressure bulging the recording tambours outward. The recording levers of these systems are then adjusted in a horizontal or other marked position, and a fall of one of these levers (within ten or fifteen minutes) denotes a leak in the corresponding system, which then must be located by the method touched on below. For certainly with the abdominal pneumograph, its tambour must also be clamped

in the stretched position, the decrease of pressure drawing the recording tambour inward, and then the recording lever must be watched for a rise.

The rectal and gastric systems, with balloons attached, are inflated to their normal pressures or a little above, and the atmospheric openings on the recording side are closed off. Then a rise in the recording lever (or float recorder) denotes a leak in the intermediate balloon or membrane — a leak into the recording system side of the intermediate chamber; whereas a fall denotes a leak balloonward to the chamber (cf. Figs. 2 and 3). The airtightness of the recording side itself is tested separately by inflating it somewhat thru the atmospheric opening and watching the lever for a fall. When a leak occurs, its exact location is found by placing clamps at various places along the system after inflation. Then if the lever drops before the release of a clamp, there is a leak on the recording side of the clamp's position, if after the release, balloonward to that position. Any leak is, of course, repaired when detected, and the system retested. The elimination of leaks, especially the renewal of tambour membranes and balloons, is not a small part of the experimenter's work.

In view of the irksomeness and time-consuming nature of the work of mending leaks, some care was taken in trying to keep the rubber material in good condition. An open dish of water was kept in the closed case in which balloons and gastric tubes were stored, and during the last month or so of the experimenta a pan of water was kept in the experiment room to protect the set-up, with the door always closed. The similar use of xylol was also suggested to provide another necessary volatile constituent of the rubber. A chemical expert on

rubber would probably be able to give some useful advice in this connection.

2. Discomfort of reactors. - During the running of the experiment, discomfort of the reactor, due to the gastric balloon and tube, is a possible handicap. It seems a considerable possibility, that, reasoning from Cannon's observations, great physical discomfort is accompanied by sympathetic effects on the gastro-intestinal organs—loss of tone for the most part. If, then, a subject does experience considerable physical discomfort during the experiment, we can suspect that the stomach will be in a constant condition of lowered tonus and will not be able to show as wide variations in tone in response to stimuli as in the more normal condition. In this connection it may be of some significance to note that the clearest positive results and the greatest tone variations were obtained in a reactor who had no discomfort at all, and that the results tended to be most negative in the case of subjects that had most discomfort. It is to be hoped that in future work more attention will be paid to this factor and its adequate recording than was paid in the present work.

3. Difficulties in blood pressure recording.— The continuous blood pressure recording was undertaken mainly in connection with the adrenin experiments; but the attempt was made to extend its use in connection with the other stimuli, without success, however. The Erlanger method is a crude method and does not show the finer changes, while the Kolls method, which when working properly should show the finer changes quite well, proved too difficult in its adjustments for combination at this stage with the balloon method,

itself difficult enough to manage.

In connection with these continuous methods, one might expect some difficulty of the sort discussed under 2, above, because of the discomfort caused by the long application of pressure to the arm. But in the records there can be observed no tone decreasing effect of the constant pressure over the length of time it was necessary to keep it applied. The discomfort experienced in this connection is much more localized and less general than that discussed under 2.

4. Unreliability of the introspective reports.— There are several difficulties that may interfere with the reliability of the simple introspective reports obtained in connection with these experiments. In the first place, they may not always be veracious— not, that is, thru any conscious effort of the reactor to fake or deceive. But he may be influenced by a certain amount of pride to cover up, from himself as well as from the experimenter, especially his fear reactions, or at least to minimize them. In the case of two reactors, this was suspected; but on going over the reports and records, the experimenter believes that such suspicion may probably have been unjustified— except for a small amount of minimizing in one of the cases. On the other hand the reactor may be influenced to exaggerate somewhat the reactions experienced, thru desire to please the experimenter with something positive. The writer has no such case in mind, however; the reports seemed to be on the whole judicious and veracious to the best of the reactor's ability to remember and express their reactions.

The verbal expression of an emotional experience always offers difficulty, but less of course in the case of the more clear-

cut reactions of fear, startle, amusement, disgust, relief, reported in the experiments. The difficulty of memory, however, seems somewhat more formidable. But tho it was not possible for the reactor to remember his reactions to the minor incidental stimuli, he seemed in most cases not to have trouble in remembering the reactions associated with the major stimuli as he was reminded of the latter. The subjects did not hesitate to say that they did not remember the procedure or the reaction in question, or that they were hazy on it. Where the introspective signal has been used, and the reactor has to account for each signal mark, the task is harder. This has been discussed in connection with the stimulus of reading letters. In one experiment with the usual run of stimuli the introspection signal was used, and the reactor, skilled in the technique of introspection - retrospection - report, made the attempt to remember the meaning of about thirty signal marks. There were two or three discrepancies in the result, and the whole thing could not be considered very reliable, tho of course the subject did have the stimuli to associate to. It might be possible to use this technique if introspections were reported after each set of major stimulus procedures instead of with but one break in continuity of the record, as was done in the experiment under discussion.

However, the introspective reports obtained by the usual method were, it is believed, sufficiently reliable for the purpose of the present experiments. This purpose being to investigate possible changes of tone in the gastro-intestinal organs in response to emotional stimuli, the use of the introspective reports was to check whether the stimuli were actually "emotional" ones and to give some information at least on the general nature of the emotions

called out.

5. Difficulties involved in arranging the stimuli. — The difficulty of procuring adequate experimental emotional stimuli has been already discussed at the beginning of the section on stimulation. Undoubtedly further and still more successful efforts can be made to overcome these difficulties.

6. Spontaneous or "automatic" rhythmic tone changes. — It is evident that the rhythmic hunger waves and other more or less rhythmic changes of tone in stomach and intestines will make the records more difficult to interpret. The reactor swallows the balloon usually within an hour after a meal, in order that the hunger tonus waves may be eliminated from the stomach tracing; but even so, they usually appear during the experiment, at least in shallow form. The hunger contractions of the duodenum (cf. Carlson (5), p.82) are much more irregular, and therefore are likely to interfere more with the interpretation of records. Digestive contractions of the stomach seem to make no impression on the balloon, probably because they are of the form of peristaltic waves mainly in the pyloric half of the stomach (Cannon (4)), as compared with actual contractions of the entire stomach in hunger (Carlson(5)). Rhythmic tone changes and contractions of the rectum were recorded during the experiments. It is possible that the use of the enema would eliminate most of these.

When the emotional effects are clear cut, however, they can be observed superposed on the automatic rhythm. Such is the case in one of the best records obtained (Fig. 14). The effect of the stimulus on the rhythmic changes themselves is also of interest.

7. The intra-abdominal pressure component. — A great

difficulty in the interpretation of the records and a real limitation on the certainty of the balloon method, as applied in the present work, lie in the fact that the recorded variations in total pressure on the balloon are caused not alone by changes in tone of the containing organ, but also by variations in intra-abdominal pressure. These latter variations, resulting from respiratory and other activities of the diaphragm and the thoracic and abdominal muscles, could not be checked with any certainty by means of the method used — the pneumographic recording — as will be explained presently; and no simple and sure method suggested itself.

The difficulties will become clear from a consideration of the pneumographically recorded girth changes and their relation to the variously caused changes in intra-abdominal pressure. It has already been explained in the discussion of the apparatus that *increased girth* of the *chest* is recorded by a *rise* of the thoracic writing lever, of the *abdomen* by a *fall* of the abdominal lever.

Let us first consider the changes that take place in normal respiration, in which both diaphragm and thoracic wall muscles play a part. Both these systems act in inspiration to increase the volume of the thoracic cavity. Certain of the thoracic muscles lift the ribs outward and upward, thereby increasing the girth of the chest; and the increased girth is recorded by the thoracic pneumograph system. At the same time the diaphragm is acting. The diaphragm is at the start in a relaxed condition, arched upward, convex toward the thoracic cavity, which it separates from the abdominal cavity below. In inspiration the muscular diaphragm contracts, flattening downward and encroaching on the volume of the abdominal cavity. As a consequence, there is an

increase in the pressure on the semi-fluid and gaseous contents of the abdominal cavity, as evidenced by the recorded rise of pressure in the balloon, keeping step with the progress of inspiration as recorded by the thoracic pneumograph. ( The simultaneous ordinates show this.) It is this increase in intra-abdominal pressure that bulges the abdomen, causing the increase in girth recorded by the abdominal pneumograph. The bulging of the abdomen is brought about partly thru the elasticity of the abdominal wall, including its muscular layers, and probably in part thru reflex relaxation of the abdominal musculature (cf. Coombs (13)).

In expiration the reverse changes take place. The ribs are dropped downward and inward, and the girth of the chest is thus decreased, as recorded by the chest pneumograph. And the diaphragm relaxes and is drawn upward into its arched position again by the collapsing elastic lung tissue. Thus the volume of the thoracic cavity is diminished, and expiration takes place. But the relaxation and drawing up of the diaphragm decreases the intra-abdominal pressure, as the balloon record shows, and the abdominal wall is drawn inward, acting thru elasticity and probably thru reflex coordination of the abdominal muscles as well. The abdominal pneumograph system records a decrease in girth.

Thus, the chest pneumograph records thoracic respiratory activity directly; the abdominal pneumograph records only a result of "abdominal"respiratory activity, as the action of the diaphragm cannot of course be recorded directly.

Under certain conditions, respiratory movements of the chest can affect intra-abdominal pressure. If, with diaphragm more or less passive, the chest is expanded very suddenly, the intra-

thoracic pressure drops so considerably that the passive diaphragm is drawn upward. A decrease in intra-abdominal pressure follows, with diminution of abdominal girth. This may happen with the glottis closed or open, though it will be more marked in the former case. Exactly this occurrence took place in the early experiments on the duodenum with the experimenter himself as subject, and the resulting fall in the duodenal pressure level was first mistaken for an emotional tone change of the duodenum. Only abdominal respiration was being recorded besides the duodenal pressure, and a strong interrupted electric shock from an inductorium was being taken as stimulus with respiration suspended at expiration (for the clearer detection of tone changes). A sharp drop of the duodenal level usually followed upon stimulation (Fig.9-a,b, and c). But a sudden spasmodic expansion of the chest was noted, also following the painful stimulus, and when this movement was tried voluntarily, without a stimulus, the sharp duodenal drop was produced (Fig. 9,d).

This led to the adoption of the thoracic pneumograph, and in a following experiment, using both pneumographs, the two procedures were repeated - stimulation and voluntary chest movement - and the matter was thus further clarified. Some of the records showed not only the expansion of the chest, but also an accompanying decrease in girth of the abdomen, indicating a decrease in the intra-abdominal pressure. The same can be seen in Fig. 9. This efficacy of the abdominal pneumograph in indicating changes in intra-abdominal pressure caused by chest movements, as well as by those of the diaphragm, would have led to the discarding of the thoracic pneymograph as unnecessary, had it not been for the realization of the ambiguity that will be discussed presently.

However, to conclude the discussion of chest effects on intra-abdominal pressure, it should be pointed out here that if, with passive diaphragm, the sudden chest movement is a contraction instead of the expansion discussed above, then the diaphragm is forced downward by the increase of intra-thoracic pressure, and an increase of intra-abdominal pressure ensues, with a forced increase in abdominal girth. This occurs in a forced thoracic expiration. The increase in abdominal girth indicates increase in intra-abdominal pressure. But in the more usual forced expiration, an active contraction of the abdominal muscles is also involved, adding to the increase of intra-abdominal pressure and forcing the diaphragm upward. In this case a decrease in abdominal girth is associated with increase of intra-abdominal pressure. This brings us to the ambiguity of the abdominal pneumograph records.

For changes in abdominal girth, as recorded by the pneumograph, would give true indications of changes in intra-abdominal pressure consequent upon action of diaphragm or chest muscles, only if the abdominal wall were simply an elastic tissue without muscular elements, or at least if the tone changes of the abdominal muscles were all reflex consequences of changes of intra-abdominal pressure — relaxation caused by increased pressure, contraction by decreased pressure, as in normal respiration. If either of these suppositions were true, increased girth of the abdomen would always mean increase of intra-abdominal pressure, and decreased girth decreased pressure. But independent activity of the abdominal muscles is altogether probable, especially in emotions, and would affect intra-abdominal pressure in such a way as to reverse the rule given above. For independent contraction of the muscles, involving decreased girth, tends

to increase pressure, and independent relaxation, involving increased girth, tends to decrease pressure.

It must be remembered at this point that because of the continuous presence of the respiration changes, we are, in interpreting the records, dealing with alterations in level of the tracings, rather than with direct upward and downward movements of the tracing lines. The expiratory level is the clearest to follow, because it changes much less than the inspiratory level. If, now, the abdominal level in the record rises, showing decrease in girth (see page 10 ), and at the same time there is a comparable fall in the stomach level, keeping step with the abdominal rise and mirroring it, as it were, then there has been a decrease in the expiratory intra-abdominal pressure in consequence of a change in the expiratory tone of the respiratory system, and a relaxation of the stomach cannot be adduced from the recorded fall of the stomach level. And if with the rise of the abdominal pneumograph level (decrease of girth) there goes a parallel rise of the stomach level, then there has most probably been an increase in intra-abdominal pressure level due to independent increase of tone of the abdominal muscles, and a contraction of the stomach cannot be adduced. Similar statements hold for contrary and parallel motion of stomach level with fall of abdominal level (increased girth) the rule being that with contrary motion (the more usual in the records) the change in i-a pressure is due predominantly to a change in respiratory level, while with parallel motion, the cause of the i-a pressure change is predominantly an independent alteration of tone of the abdominal muscles.

Thus, when a regular change in stomach (or rectal) level is accompanied by any regular change of abdominal pneumograph level,

a positive result cannot be adduced— unless the gastric change is clearly much greater than could be accounted for by the abdominal change; and this would be difficult to determine in the absence of any systematic quantitative controls. But if definite changes occur in the stomach level without appreciable change in abdominal level, and if such is the case with any regularity, then the probabilities, at least, favor a positive interpretation of actual visceral tonus change. If, for example, a drop in stomach level in such a case is to be interpreted as an artefact from decrease in intra-abdominal pressure, the explanation would have to be as follows: The expiratory position of the diaphragm has risen (decreased expiratory tone), diminishing the expiratory level of i-a pressure and tending to draw the abdomen inward (decreased girth). But at the same time there has been a relaxation of the abdominal muscles, which tends to increase girth, of such an amount as to cancel or balance exactly the girth diminishing tendency of the diaphragm's change, with the consequence of still lower i-a pressure, recording in the balloon system — and all this without change in abdominal pneumograph level. This perfect balance might occur once, but would hardly be expected regularly. Any claim of positive results with this method must be based on the occurrence of many of these cases.

If there are simultaneous irregular changes of both abdominal and balloon levels, contrary and parallel motion occurring in a mixed-up manner, then nothing can be adduced. But if irregular changes of abdominal level are accompanied by a regular change in balloon level, then the presumption is in favor of a real tonus change.

It is hoped that the principles are now clear upon which

interpretation of the records is based. The chest pneumograph was retained as a possible additional check, in view of the ambiguity of the abdominal record, it being suspected that in gradual changes of respiratory level both chest and diaphragm take part (the chest effect discussed above was a sudden change). The thoracic record might then give an indication of whether an abdominal change is diaphragmatic or independent abdominal in origin.

Two possible extraneous influences suggested themselves as dangers to the validity of the rectal records - movements of the legs, and contractions and relaxations of the striped muscles near anus and rectum (levator ani and sphincter externus for example). The latter group of muscles can be contracted and relaxed voluntarily, and therefore control records were made with one reactor in two experiments, using both movements of the legs and changes of the anal muscles. These seem to be not unlikely occurrences in some emotional reactions. Rectum, stomach, and both pneumographs were recorded. The subject was directed to raise his knees at the command "up" and to lower them at "down". After several repetitions of this, he was directed to contract the anal muscles at the command "contract", to relax them at "relax". The experimenter, of course, signalled at each command. The anal changes appeared too sudden in the first tries, and the reactor was asked to slow them, if possible. The control records are reproduced in Figs. 11, 12, 13. (Note rectal tonus waves in Fig. 11, following anal contraction procedures).

Raising of the legs is seen to cause a rise of the rectal level, their lowering causing a fall; but these changes are accompanied by similar changes in gastric and abdominal levels, in two cases particularly — the first and third of Fig. 12 — the gastric

tracing paralleling the rectal, the abdominal mirroring it, showing that the rectal change is due to a change in i-a pressure (result of the leg movements). In general, the gastric and rectal tracings are each a check on the other: if their changes of level are exactly parallel the changes are most probably pressure artefacts, unless the abdominal level is unquestionably constant. In the case of leg movements, then, their pressure effects are shown both in the stomach and in the abdominal records, and if the general principles of interpretation are adhered to, they would seem less to be feared than was expected. It cannot be denied, tho, that they contribute another element of doubt to the results of this method.

In the second control experiment the procedure was tried of tying the legs down to the couch, not uncomfortably, with a linen strip, just above the knees. Then the attempt to lift the knees had in one case (as the record of Fig. 13 shows), no effect, in another a reversed effect, associated probably with i-a pressure changes involved in the effort made. In all later rectal experiments the tying of the legs was resorted to as a safeguard. Perhaps it should be used in connection with all the experiments on stomach alone, in view of the effects on gastric level demonstrated in the control record. But the addition of extra annoyances does not seem desirable, and the abdominal check should be enough.

As for the changes of the anal muscles, their contraction causes a rise, their relaxation a fall in the rectal level. Here, too, the rectal changes are for the most part reflected in the gastric and abdominal tracings — not so well in the record of Fig. 11. For the elimination of the possible anal muscle

effects in the records, we must again rely on our general principles of interpretation. Sudden, abrupt changes in the rectal level are to be looked on with more than suspicion; but that slower changes due to anal muscles can occur is shown particularly by the next to last case in the record of Fig. 13 — well checked, however, by the abdominal tracing.

8. Vascular reactions in the viscera. - A final additional ambiguity in interpretation presents itself in the possibility of plethysmographic effects in the abdominal cavity. It is well known (cf. Cannon (3), Chap II) that the effects produced by the autonomic nervous system include besides smooth muscle tone changes of the gastro-intestinal and other visceral organs, also tone changes of the smooth muscle of the blood vessels all over the body, including the visceral vessels in the abdominal cavity, causing constrictions and dilations of the vessels and shifts of the volume of blood from some parts or organs to others. For example, excitation of the sympathetic division of the autonomic nervous system, which causes in general relaxation of the smooth muscle of the gastro-intestinal tract (loss of tone of the organs), causes also constriction of the blood vessels of most of the abdominal visceral, particularly of the gastro-intestinal tract and its mesenteries, with dilation of vessels in the voluntary muscles and other outlying parts, and a consequent great shift in blood volume from the abdominal cavity to the outlying parts.

Now one might expect that such a shift of blood volume would have some effect on the intra-abdominal pressure — the i-a pressure should be diminished by the removal of a considerable

volume of blood from the abdominal cavity. This diminution of i-a pressure would be marked in our experiments by a fall in the balloon level, which also marks the other sympathetic effect - decreased tone of stomach or rectum. There is a possibility, then, that a fall (or rise) of stomach level, for example, is caused not only by loss (or gain) of tone of the stomach walls, but by a simultaneous abdominal vaso-constriction (or dilation). Indeed, the latter might be the sole factor. That such is the case, indeed, is assumed by Ernst Weber ((10),p.115) in his work with the balloon method (on the rectum). But he does not satisfactorily rule out, it seems to the writer, the possibility of tone changes of the rectum, even tho he took pains to eliminate peristaltic waves — a different thing.

And there is a consideration, at least in the present experiments, that argues against the presence of the vascular factor in those changes of balloon level which are considered positive evidence of real gastro-intestinal changes in tone. If the vascular effect on i-a pressure is great enough to affect the balloon level, it should also be great enough to affect abdominal girth as registered by the pneumograph. This is clear from a comparison of the respective sensitivities of the balloon tracing level and the abdominal level to intra-abdominal pressure changes due to respiration and changes in respiratory level. These sensitivities are both of the same order. Consequently when there is a variation in balloon level without any in abdominal level, we cannot consider a change in abdominal blood volume as part of the causative factor. Such a vascular reaction may probably be taking

place at the same time as a recorded tone change of gastric or intestinal wall, and would most likely provide an important part of the emotional reaction and content; but the volume change involved seems to be too small a proportion of the total i-a volume to show an i-a pressure variation by the abdominal pneumograph system, or, therefore, by the balloon system, since the sensitivity of both seems to be about the same. With the use of adrenin we do get the rise in abdominal level, pari passu with the fall of gastro-intestinal level. The vaso-constrictor effect in this case, it is surmised, is extensive enough to be recorded.

Another allied point is capable of provoking some thought. The inflated balloon forms a part of the intra-abdominal volume. Now when the somach contracts, some air is forced out of the balloon into the recording system: there is a diminution of the i-a volume. Similarly, a relaxation of the balloon-filled stomach, allowing air to enter the balloon, should occasion an increase in i-a volume. One might expect these volume changes to affect the abdominal girth as recorded by the pneumograph, in which case we could not get variations in balloon level without parallel variations of abdominal level. But that is what we do find in many cases. When the rhythmic tone changes, indeed — the hunger tonus waves of Carlson — are well marked (as in the records of Reactor Gro., Figs. 14 to 18), the abdominal level shows no definite parallel changes, and we also find the same to be the case with the tone changes presumably produced by emotional stimuli. The explanation again must be that the volume changes in the balloon are too small in proportion to the total i-a volume to show in our records.

## III RESULTS.

In the presentation of results, liberal samplings of the most convincingly positive and the most contradictory records will be shown and discussed, and also some of the intermediate records. Then, for the sake of presenting the results in their entirety, tables of two kinds will be shown — detail tables and summarizing tables, made separately for stomach and rectum. The results for the duodenum were too meager to warrant separate tables, and have been included in the stomach tables without confusion, as will be explained later.

### 1. Discussion of Kymograph Records.

The records of reactor Gro. showed the clearest positive results, and therefore can serve as a starting point for making clear the interpretation of the tracings. Figure 14 shows tracings of both stomach and rectum with stimulus of turning out the light. At the top is the time line with intervals of 5 seconds (as always in these experiments). Next below is the rectal tracing, showing a leak in the rectal balloon, necessitating an adjustment of the writing lever a short way before the first stimulus ordinate mark. Next the tracing of the abdominal pneumograph, with increased girth (as in inspiration) recorded downward, next that of the thoracic pneumograph - increased girth (inspiration) upward, and next the stomach tracing. Finally at the bottom is the stimulation signal line. In both stomach and rectal tracings an upward movement indicates increase of pressure in the internal balloon (inspiration upward, expiration downward), a rise in level showing increased muscular tone or contraction of the organ, a fall showing decreased tone or relaxation, when independent of any changes of intra-abdominal pressure as indicated by the abdominal pneumograph tracing.

The control record before the stimulus shows tonus waves in the stomach such as those described by Carlson (5), but of longer period. The rectum shows but little change except for the leak, and presents a quite horizontal level just before the stimulus. When the light is turned out the stomach tracing drops in two respirations to a level slightly lower than that of the trough of the preceding tonus wave, the level recovering toward the end of the stimulation period and after the light is turned on. The expiratory level of the tracings is always the one considered, and since that of the abdominal tracing remains horizontally constant, the changes of stomach level can be considered to indicate real changes of tone of the stomach — loss of tone or relaxation at the presentation of the stimulus, increase or regaining of tone (contraction) at its removal. The rectal tracing shows the appearance of rhythmic contractions and relaxations following upon presentation of the stimulus and their gradualy disappearance after it is removed, together with a slight but unmistakable increase of general tone while the light is off and decrease after it is turned on (as judged from the low points of the successive tonus waves). The subject reported later that when the light was turned off he got tense, waiting for what might come. For the purpose of tabulation of results, this reaction is designated as marked on the figure -- the rectum at the top, for the stomach at the bottom. For the rectum, the top line signifies that the tonic level rose following the presentation of the stimulus, fell following its removal; the middle line shows increase in rhythmic contractions upon presentation, decrease upon removal; and the lowest line records by abbreviation the introspective report of the emotional reaction - tenseness.

For the stomach, the middle line is omitted because no effect on the rhythmic activity can be determined; for the tonic fall that has been adduced occurs unfortunately just about where the rhythmic fall would have taken place. That makes this particular result less clear than one would like to have it. It is an example, however, of a tone change clearly superposed upon rhythmic changes.

The rhythm appears again in the stomach before the second turning off of the light. It is arrested by the stimulus, the tone drops, recovers slightly, drops again. The introspection was "Less tense". In the designation of so much of the reaction as appears in the figure, the upper line again refers to the tonic level, the middle to the rhythmic activity. Quantitative relationships cannot be considered in the tables, and "Less tense" is rendered merely by T. It is interesting to note, however, that the fall of tone is less than before. The abdominal level remains constant. In the rectum no effect can be noticed, apart from the leak and the dying out of the rhythmic effect of the first stimulus, and the reaction is labelled with a zero. The middle line of the designation is always omitted unless some change in degree of rhythmic activity occurs upon either presentation or removal of the stimulus. When only one figure appears in the first or second line of the designation, it refers, of course, to the presentation, not the removal of the stimulus.

Figure 15 shows what occurred at the same reactor's first experience of the threat of electric shock. The stomach tracing shows vigorous rhythmic activity preceding the announcement, in Fig. 15a. The rise just preceding the signalled end of the announcement is an example of many such rises that take place while some announce-

ment is being made and may be connected with some emotional concomitant of directing the attention. Hence, its designation. It is probably only the short rise for about five seconds before the ordinate mark that should be considered in this connection, as the announcement: "I want to try a powerful electric shock" does not take more than five seconds to make. Just following the announcement, after one expiration, is a precipitous drop of the stomach level, while no appreciable change in the abdominal level is taking place. After that the reactor remonstrated verbally, all sorts of respiratory disturbances showing in the record. He mistrusted the apparatus and feared the amperes. In the middle part of the record, omitted in the figure, while the talking was going on, the tone stays low, and thru the irregularities it can be seen that the rhythmic changes are absent. Undoubtedly there was a strong fear reaction — the emotion was admitted by the reactor. For the rectum (an adjustment precedes by about 20 sec.), no "attention rise" is seen, tho there is a dropping out of rhythm. No appreciable change is seen just following the announcement, but for the rest the record is questionable or indeterminate, completely upset by the respiratory disturbances. The reaction is recorded, therefore, with a question mark. The end of the procedure is shown in Fig. 15b. The experimenter wanted to reserve this good stimulus for further use, and therefore announced, "I guess I won't do it to-day." The rectal record is spoiled by the leak. In the stomach record, however, the level has remained low, tho irregular. The possible attention rise precedes the signal, a steady rise follows it, over and above any abdominal effects, and the rhythmic activity

returns. The reactor felt relieved, naturally enough.

Five days later the shock procedure was carried thru completely with the same reactor, without the announcement. The reactor reported that he was still afraid but had decided to go thru with it. There was no great respiratory disturbance, and the record is much clearer. It is presented in Fig. 16. The loss of tone of the stomach when the apparatus is brought out is well marked and the regaining of it at the end is striking. At both places where the reactor is given the handles, and fear should increase, the reaction is questionable because of change in the abdominal level, and is so recorded. After the closing of the key, without a shock, a rise in stomach tone is noted. Relief may be presumed on the part of the reactor, tho no report on it was taken. Emotional reactions thus presumed are included in parentheses when entered in the table. The slight drop following the explosion mirrors the rise in the abdominal level so exactly that the reaction is recorded as negative (0) instead of questionable or indeterminate (?). The stoppage of the kymograph during the repair of the loose connection, shows clearly about two respirations before the signal: "Fixed, ready". In the rectal tracing, at the bringing out of the apparatus there is no change in general level but the appearance of rhythmic contractions. An adjustment is seen several respirations after "Key closed". When the kymograph is restarted the rectum shows reaction where the stomach does not. At the explosion the rectum responds with a short contraction and relaxation and a series of a few rhythmic contractions. The short contraction is recorded

as [+,-], the brackets denoting that +, — is considered as a single reaction, and the comma denoting "then"; + then —. The use of the comma is again seen in the designation of the relief reaction in the rectum, there being no change in level at first, then later a fall, with a decrease of rhythms. The designation + , - is to be distinguished from + - . When no comma is present the final figure refers to the removal of the stimulus. With the comma, both figures refer to the presence of the stimulus.

Figures 17 and 18 show results obtained from the same reactor by use of the rat decay odor and the snake. In Fig. ~~18~~ 17, a stopping of rhythmic action is noted in the stomach record before the stimulus, corresponding perhaps to the approach of the experimenter — apprehension presumed, therefore (F). The sudden rise here in both stomach and rectal tracings is clearly an intra-abdominal pressure effect. When the stimulus is applied, a fall in stomach tone is noticed, followed later by a large rise after the experimenter by mistake touches the reactor's nose with the test tube, thus learning the value of that stimulus when the reactor reports disgust at it but not before. Since the reactor claims not to mind odors, being accustomed to them in chemical work, the unpleasantness not unreasonably presumed by the experimenter must be parenthetized. When the test tube is removed a slight fall is seen in the stomach level before the change in abdominal level begins. In the rectal record there are two distinct rises, the second corresponding to the one in the stomach record, with a much more unequivocal fall following removal of stimulus. The sharp fall at the very end of the stomach tracing may indicate further relief from disgust or the return of the tonus rhythm, or may be

associated with some thinking activity. The kymograph paper ended here. With no clue to the reaction one way or another, it is of course not recorded in the table.

In the snake record (Fig.18), the stomach change, tho at first sight confusable with the tonus rhythm, is upon brief study unequivocal. The tone stays low for a longer time than in the tonus waves and recovers clearly right after the removal of the stimulus. The recorded emotional reaction conflicts here with the introspective report. Tho it may be true that the subject was not afraid of snakes in general, but liked them, still it seems impossible that there should not be some apprehension lest the snake should strike. The reactor reported, indeed, that just before the light was turned out the snake drew its head back, startling the subject. In all strictness, perhaps, the reaction should have been labelled "No", meaning no emotion, and considered with the negative results, as most of such reactions were subsequently treated.

The records of Gro. are marked by the smooth regularity both of the respiration and of the changes in the stomach. It is well then to contrast the records of reactor Gra. In his case there is considerable jerky variation of the depth of breathing, usually small changes in the respiration level, and at certain times a large change of respiratory rate. In the parts of the record of March 17, 1923 that are included in the figures, the respiration is very rapid, tho in the early part of the record it was much slower. But most important is the jerky irregular appearance of the stomach tracing and the lesser irregularity of the rectal record. Whether the irregular ups and downs of the stomach tracing represent hunger activity (the records reproduced were taken between 10:45 and 11:45 A.M.),

or perhaps are associated with thinking , is a question. Gra. was easily the most nervous of the reactors in general appearance and activity. The record of March 17 shows more irregularity in the stomach than the other records.

Because of the irregular appearance of the stomach records of this reactor, the possibility of finding positive results in them seemed at first sight small. There was so much chance that the changes noticed were mere coincidences with the prevailing irregularities of the stomach and were not related to the stimuli. But when the general levels during stimulation are compared for all cases with those before and after and finally tabulated, the preponderance of the evidence is overwhelmingly against the possibility of mere coincidence, as will be seen later on in the table that summarizes the results. Figures 19 to 24 show clearly the sort of changes found in this reactor.

In Fig. 19, the stimulus is the rat. The stomach level during its presence is distinctly lower than before and after. There is some abdominal change, but the stomach change does not follow it. The rectal change mirrors the abdominal one too closely, and is therefore considered questionable. The introspective report was; "A little nervous". The various varieties of fear such as nervousness, apprehension, and the like have been classified and tabulated as fear. Tension, wonder, and "nerving up" have been kept separate.

The stomach reactions in Fig. 20 are more striking, especially the recovery of tone immediately following the turning on of the light both times. The subject reported "No effect", but there was good reason to suspect that this particular reactor was

minimizing his emotional reactions. In view of his reports in connection with other procedures, it seemed certain that some apprehension was caused by this one, and the reaction was tabulated as (F). Such an arbitrary decision may involve some question - begging, and the strict designation should have been "No". A correction will be applied for the parenthetized reactions in the summarizing of results. In the rectal tracing, the rise immediately following the second application of the stimulus may well be part of the prevailing rhythmic activity, and the reaction is classed as questionable, there being no clear change of general level. A clear fall follows the pistol shot, over and above the abdominal effect, with subsequent recovery, especially after the light is on. In the stomach, however, the rise and fall at the shot are questionable.

Figure 21 shows the reaction to the water stimulus. The startle reaction is questionable in both stomach and rectum, as is very often the case on account of respiratory disturbance. The fall and recovery in the stomach are clear. The reported uncomfortableness is tabulated as "unpleasantness". In the rectum there is a diminution of rhythmic contraction and a small drop in level, with subsequent recovery of both.

In Fig. 22 the snake is the stimulus. The subject's reaction in thought and emotion, when the experimenter entered with the box, was: "Some new torture", and a little apprehension. In the stomach at this point the change in level is upward instead of downward as we have met it before in fear reactions. In the rectum, the rhythmic contractions, so marked previously, become still larger. The level perhaps falls. In the stomach again, the precipitous fall just after the showing of the snake is probably not related to the stimulus, as the

reactor reported that he did not see the snake until it was placed upon him. A further fall follows the latter procedure. Still another slight fall follows the turning out of the light, but the rise when the light is on is questionable on account of the abdominal change. Recovery is slow after the snake is removed. In the rectum there is decrease of tone and rhythmicity, with subsequent recovery of both. The reactor "minded the snake a little", he reported, and the reaction was tabulated as fear, tho perhaps unpleasantness should have in strictness been recorded.

Figures 23 and 24 are from the record of the same reactor taken a week later. They show much less irregularity. In Fig. 23 the procedure was the pistol threat, and the introspection was complex: "Anticipation, nervous, keyed up". The first of these is not in itself emotional. The second has been classed as fear. The key to the investigator's classification of third as Ne--"nerving" or "nerving up" — is to be found in the generally rising level. In the out-and-out fear reactions the tone change is a loss, as in the case of reactor Gro, and the shock stimulus. The expression "nerving up" was the characterization by reactor R of his emotional state when holding the handles in the shock procedure. More will be said about this later on. In the record, the abdominal tracing shows jerky changes of level, tho the general level remains fairly constant. The rectal changes are too much like the abdominal ones and are considered questionable. In the stomach tracing smoother changes are to be seen, and are all rises except a gradual fall after the first fake shot and a short fall following the contraction at the real shot.

In Fig. 24 (shock stimulus) the changes in the stomach are clearer and less called in question by the abdominal complication. "Worried" is classed as F, but the reaction is questionable. The rise

associated with the taking of the handles is classed as Ne ("Keyed-up" again reported), the following large fall as F. The fall after the closing of the key is most probably associated with relief — (Rl) — and is then anomalous. There is another fall after "Fixed, ready", which is classified as (F), tho again in strictness we should tabulate No as the reactor reported that at this stage he thought the procedure a fake. The increase of tone at the end is undoubted. In the rectum the changes are not so clear.

With the above rather elaborate discussion of some of the records of two reactors, Gro. and Gra., to serve as an introduction, we can go on to a briefer discussion of the records of the other reactors, going into detail when desirable.

Tho the rectal record of reactor R. shows clear and interesting changes upon stimulation, the stomach results are less clear and are marred by a leak in the intermediate balloon, giving a constantly rising level. A portion of the duodenal record of this reactor will be presented at the end of the discussion of records. The records of Miss C. show nothing of a striking nature, and are interfered with at several important places by respiratory disturbances. One interesting result was obtained with the use of the rat decay odor, which in this early experiment was rather mild. The subject recognized rat and reported that the odor was pleasant by previous association with interesting laboratory work. In both cases of applying the odor the stomach showed small but unmistakable increase of tone, with decrease upon removal of the stimulus — not a continuing rise as in the disgust reaction of Gro. (Fig.17), but a small change to a new horizontal level.

The record of reactor B., as illustrated by Fig. 25, shows

especially the smallness of response, which is the rule rather than the exception. Contrast the stomach changes shown in this figure with those in the shock reactions of Gro. (Figs. 15 and 16). The experience with Gro. seems to support the simple view that the size of the tone changes are directly correlated with the intensity of the emotional reactions. This is especially the case with the sizable clear-cut emotional reactions. But with this very reactor, B., for example, the introspection for the pistol threat procedure was, "Scared worse than with anything else," and the tone change shown, if any (for an abdominal change makes the result questionable) is certainly not any greater than the stomach changes in Fig. 25. In Fig. 25 the first stomach reaction is a contrary one, opposite in direction to the one at the second turning off of the light, tho the introspective reports were essentially the same for both reactions. The rectal changes are small--the sensitivity of the rectal balloon system is considerably below what it was in the records of Gro. and Gra. The blood pressure record appears between the rectal and abdominal tracings, but no information can be gained from it. The Traube-Hering waves are troublesome; movement of the arm shows twice after the pistol shot.

The record of Miss L. showed a peculiar artefact. With the usual 100 cm. of water pressure in the gastric balloon system, the stomach record appeared as a straight line, without showing the respiratory waves. When the pressure was raised to 140 cm., the waves just barely showed thru. When, however, the pressure on the stomach balloon fell, because of a decrease in intra-abdominal pressure or a relaxation of the stomach, the level of the tracing fell and the respiratory waves appeared. This phenomenon is shown in Figs. 26 and

27, changes of tone being recognizable very much as in the ordinary record. The possibility has been considered that the appearance was due to the activity of an abnormally contracted cardiac sphincter of the stomach, closing off the Rehfuss tube with the help of the i-a pressure, and relaxing with the rest of the stomach under emotional stimulation. But it is improbable that the sphincter could close off the stiff Rehfus tube, and a more probable explanation would be that the balloon was kept collapsed by an abnormally high pressure of gastric content, a pressure higher than that in the balloon system. Indeed, in several cases it has occurred that 100 cm. pressure was insufficient to show the respiratory waves, an increase to 120 cm. bringing about their appearance, in all probability by opening up the balloon. In this case the pressure could not be raised above 140 cm. because of the shortness of the measuring manometer. When, however, the intra-gastric pressure fell below 140 cm., thru decrease in i-a pressure or relaxation of the stomach, then the balloon was allowed to open and become inflated. Figs. 26 and 27 show both the abdominal and gastric effects. The rectal tracing is absent; otherwise the order of tracings is the same as in previous records. In Fig. 26 the reaction to the snake is probably gastric (respiratory disturbance precedes, when reactor saw the snake); the reaction to the light is clearly gastric. In Fig.27 both components are active: there is a gastric fall before the stimulation, the changes during the stimulation are largely abdominal, and there is a clear gain of gastric tone after the stimulation is over. At all times the tracing does not rise above a certain level — the level indicating an intra-gastric pressure around 140 cm., at which the balloon is collapsed.

The record of reactor Miss B. is of sufficient interest and importance to make desirable the presentation of several selections from it in Figures 28 to 32. In these records the introspective signal line is to be found at the top, the order of tracings being otherwise the same as that in the case of Miss L. Miss B. was the reactor who was skilled in the introspective method.

In Fig. 28, the stomach reaction to the water stimulus is indeterminate because of the respiratory disturbance, and the apparent fall of tone immediately following the surprise reaction, that one might suspect to be associated with an unreported unpleasant feeling, is also questionable,due to changing abdominal level. The ordinate mark corresponding to the beginning of the second introspective signal("Pleasantness") falls on a rising part of the gastric tracing, a true rise of tone preceding it and also following it. And 10 to 15 seconds later begins a most pronounced tonic rise, not associated with any introspective signal mark, such as in four other instances follows pleasant emotional reactions (amusement or relief), two cf these instances being shown in Figs. 29 and 32.

In Fig. 29 the reactions to the snake situation are shown. The signal for apprehension after the closing of the door corresponds to a lowered gastric level. The drop in tone follows the stimulus directly, the appearance of the emotion is signalled some 15 seconds later, and its disappearance is not marked by any recovery of tone. The reactor attempted to signal the duration of each emotional feeling by closing the key at its onset and holding it closed until the feeling subsided. The reaction to the actual presence of the snake is indeterminate, as is also that corresponding to the signalled amusement as a whole, tho a rise of tone can be detectea where the arrow

has been placed. A distinct rise is seen following the signalled end of the amused feeling, one of those mentioned in the preceding paragraph, resembling the pronounced rise in Fig. 28. Whether the precipitous fall from this height, just preceding the showing of the snake, is an independent matter or corresponds to the approach of the experimenter, cannot be said. The beginning of the signalled emotional reaction to this stimulation - unpleasantness, apprehension, and disgust - practically coincides in time with the signalled presentation of the stimulus; and being marked by a lowered stomach tone, the reaction is designated as minus. When, as in this case, a complex introspection is associated with a single tone change, the reaction is tabulated in the detail table as a single one, with inclusion of all the emotions reported. The recovery of tone, following by some 15 or 20 seconds the signalled end of the introspected emotional reaction, is tabulated as a presumed (parenthetized) relief reaction, there being no report on it. The stomach reaction corresponding to the signalled emotion of amusement when the experimenter showed his bleeding hand — this reaction is quite indeterminate. In the marking of ordinates, a signal mark was made on the introspective line to show the point of time where the stimulus came in. Thus an extra mark on the other tracings is avoided — the place of the signalled emotion can be measured in. Again a rise follows the introspected pleasant emotion, and again it is tabulated as a presumed reaction.

Figure 30 shows again a disgust reaction of the stomach. The stimulus was the rat decay odor. Only unpleasantness was reported for the first part of this record. A fall in tone cannot be adduced, for the changes, tho larger than the abdominal ones,

mirror the latter too closely. After the announcement of the nature of the stimulus, however, disgust was felt, and the stomach level shows distinct rises following both touch stimulations, the rise at the announcement being thrown out of court by abdominal change. The final rise is of large amplitude, and the fall is steep following the removal of the stimulus. The signalled "feelings", as was reported by the reactor, keep step with the respirations, except that the "introspection" just before the last one signalled is "missing" as determined by comparison with the respiration record. There is then a puzzling peculiarity at the end of the stimulation period, brought out more clearly at the time of writing by the addition of a mark on the introspective line corresponding to the removal of the stimulus and one on the stomach line corresponding to the end of the last signalled introspection. It is clear then that the final two inspirations of the stimulation period, occurring when the stomach tracing is at its highest level, are not accompanied by any signalled feelings of disgust or unpleasantness. If the recorded increase of tone is the source of the feeling of disgust, it seems at least unlikely that the subject should for any reason overlook that feeling just when it should be at its height. A theoretical explanation of this anomaly might be possible, on the grounds of a shift in attention — the reactor reacting to some stimulus or situation outside of the situation involved by the present introspective task. Indeed, in this very case the reactor reported that she became bored and indignant at the long exposure to the stimulus; but only the disgust feelings were signalled. Tho, therefore, a record such as this one cannot be considered as weighty evidence against an hypothesis such as the James-Lange theory, nevertheless it is one of the records that

bring out clearly how far these preliminary experiments come from establishing the truth of a view of that sort. Improvement is necessary both in the objective technique and in the application of the introspective method. Experiments such as these offer a fruitful field for the combination of both objective and introspective methods at their best.

A similar anomalous result occurred with the use of the fecal odor as stimulus, together with still another anomaly. A considerable rise occurred in the tonic level of the stomach toward the end of the stimulation period, very much like the rise shown in Fig. 30, but of smaller amplitude. The introspection signals again follow the respiration; but signalling does not occur during the up swing of the stomach tracing, occurring again at the top of the climb and continuing during the fall to a low level, where the stimulus was removed. With the previous use of the urine odor, only a fall in level occurred, the introspection being "Distinct unpleasantness". With the fecal odor the introspection was: "Unpleasantness only", as contrasted with the disgust caused by the rat decay odor (Fig. 30). Nevertheless, the stomach shows a rise in tone like that exhibited in disgust. It is very unlikely that the reactor should have overlooked the feeling of disgust in this instance, or that there was any slip in memory, with the report so explicit.

Figure 31, however, shows the kind of result that would tend to support the James-Lange theory. The stimulating technique is that of the pistol threat. The stimulus signal for placing the pistol in position was omitted by mistake, but the first introspective signal marks approximately where it should have come in. The

The reactor reported that at first she signalled amusement — she was amused because she thought the pistol was a toy. This corresponds to signal I and probably II, though the subject's memory was hazy on the exact number of signals at this point. Signal I comes in where the stomach tone has just begun to rise, II where it has reached its height. After this Miss B. signalled at a point where she felt tense and apprehensive, qualifying the feeling, however, by reporting that it was largely verbal (the pistol might not be a toy). This is signal III, starting after the gastric tone has fallen to a low level. The next two signals occur right after the two fake shots, the reactor reporting amusement when the pistol did not go off. There is surely no "amusement rise" at these points — a fall, perhaps, at the first, made questionable by abdominal change; no change at the second. This might be explained by the possibility that the fear reaction was still dominant in the stomach, amusement making itself felt in some other organ or organs (vascular perhaps); but nevertheless, it is another insecure point that would need explaining. No stomach change accompanies the startle reaction, and the following appreciation of the stimulating technique is accompanied or followed by a slow rise of tone, which is probably associated also with general relief.

Figure 32 shows again a stomach contraction associated in some way with relief — the experimenter had announced the end of the experiment. But again we find introspective signal during the up swing and not at the top — also during the down swing, tho at a level raised above the average. (The ordinates mark the beginning of the introspection signal).

The possibility suggests itself that the tonic rises

found in the record of Miss B. in connection with the odor stimuli, and in some connection with pleasant emotions, represent independent activity of the stomach, the appearance of which is associated with the stimulation only by coincidence. However, the tonic contraction during the odor stimulation was obtained from three of the four other reactors who reported disgust (Gro., Miss G., and K), tho it was absent in the fourth (R). These contractions may be related to the contraction of the stomach in vomiting. Cannon ((4) p.57) observed with the fluoroscopic method that in vomiting there is involved relaxation of the upper or cardiac portion of the stomach and contraction (tonic and peristaltic) of the lower or pyloric part (antiperistalsis rare). The upper relaxation was the first effect prominent in the fluoroscope, but it is possible that as registered by the balloon method the lower tone gain should precede,perhaps in smaller measure than would show in the fluoroscope.— As for the tonic rises in Miss B's record, apparently associated with pleasant emotional states, five of them occurred after the signalling of pleasant states (including those in Figs. 28, 29, and 32), and one at the same time as the pleasant emotion (Fig. 31). One such contraction appeared after the kymograph had been stopped for a time and restarted, and there is no clue as to any emotional state associated with it. But no such rise (apart from those with the odors) was similarly associated with an unpleasant emotional state. It seems clear then that if the tonic rise does not condition the pleasant emotion, and even if it is an independent activity of the stomach (like the hunger contractions), it is itself dependent upon the pleasant emotional state, and to that extent is associated with the latter and is not a mere coincidence. At any rate, this state

of affairs proves a sticking point for the James-Lange theory, as far as the stomach is concerned.

The records of Miss G. are marked in part by the presence of negative results, some of which consist of actual stomach changes when the report is of no emotion. Such are shown in Figs. 33 and 34. In the former the level starts to drop some 10 to 15 seconds after the closing of the door (the very first stimulus of the experiment), but the reactor claimed she was not apprehensive. Some independent stomach activity preceded this, and it may have been that the loss of tone was associated with some emotion connected with thinking activity of the reactor. The reaction must, however, be tabulated ~~as~~ No, and in the statistical summing up must be classed with the negative results. A similar result is shown in Fig. 34 following the experimenter's entrance into the room, the reactor claiming there was no emotional effect. In Fig. 33 is also shown a more positive result with the turning off of the light — a fall in tone ("Wondering, expectant — not apprehensive"), and a rise following the relighting. The second time the light was turned off, the same two changes took place, but the report was: "No effect — I assumed composure", which implies that there really was some effect, which was compensated in some way. The reaction is tabulated again, however, as negative No. More strikingly negative is the result with the shock technique. The emotional reaction at the announcement of the "powerful shock" was "Terrible fear", but there is no change in stomach tone. There is some respiratory disturbance, but it is clear thru it that there is no decided change, just as clear as it is in the first shock record of Gro. that there *is* a sharp drop. With the taking of the handles there is less fear, but no stomach change — a slight "nerving up" gain of tone as the experimenter counts "One, two, three", and a further rise

with relief after the closing of the key with no shock. Again with the handles there is fear but no gastric change recorded.

Fig. 35 shows two small disgust contractions with the rat decay odor, both at the moments when the test tube touched the reactor's nose, which the reactor "minded decidedly". Tho disgust was reported as the general reaction to this odor, the only changes noted besides the two already mentioned are a dropping out of the tonus rhythm that preceded and a fall of tone at the end of the stimulation period with recovery after it.

The record shown in Fig. 36, obtained a few days later with the same reactor, using the snake as stimulus, is of interest, especially as the introspective signal was employed. When the experimenter entered the room with the snake box, a fall in stomach tone followed, and the report was that the reactor was scared at this point, tho the emotion was not signalled. The first introspective signal — "Scared" — comes at the bottom of a clear fall of tone. At this point, the reactor reported afterward, she "tried for composure but couldn't attain it". Therefore the rise just following this first introspective ordinate is classes as "nerving up". The clearness of the tonic rise is somewhat obscured by abdominal changes, but is quite regular, while the abdominal changes are smaller and irregular. At the next scared signal, the tone has again dropped. No change has taken place before the next introspective signal, so the reaction is considered negative. The rise following this point is doubtful— the stomach level changes exactly as the thoracic level does, tho the abdomen seems to strike a balance. This whole reaction of "increased scare" is obscured by respiratory disturbances, and the following fall of

level in relief (reported but not signalled) coincides with the change in abdominal girth. All the following reactions ("Scared at every move") are obscured by the respiratory irregularities and are lumped together as one questionable result. The reaction of "great relief" when the snake was put away is also indeterminate — the introspective signal comes at exactly the same time as the stimulus signal, and respiratory disturbance obscures the course of tone. The following incidental amusement reaction is signalled at the end of a drop of tone, not at a high level as we might expect.

It was with this reactor, Miss G., that the reading stimuli were used to best advantage, and Figures 37, 38, and 39 are included to show the results of these procedures. In all these the introspective signal line appears at the top. Figure 37 is a "norm" or "control" record showing the spontaneous stomach rhythm at the start of the experiment. This is most probably a hunger rhythm, as the subject had been too excited over some news that had been received in the morning mail to eat but little for breakfast. Figure 38 shows the behavior of the stomach tone during the reading by the experimenter of two passages from Barbusse's "Under Fire". (The time clock was not in operation). "Pity" was signalled just before the end of the first selection, but no sure change can be detected coinciding with the signal. An increase in the amplitude of the tonus waves follows the end of the reading, with no change of the lower level of the waves. The reading from this book was rather irksome to the subject, and as the amplitude of the wave decreased during the reading, it may well be that the increase of the wave after the end is associated with relief, which is tabulated as a parenthetized reaction. During the reading of the second selection

disgust was signalled. A tone change cannot be adduced, the tonus wave going on its way entirely unruffled, as we compare it with the previous wave. Again there is an increase of the wave's amplitude after the close of the reading, with this time a considerable gain of tonic level. The signalled emotional reactions to this reading were sparse, and the effects on stomach tone were uniformly null. This may well be connected with the fact that the emotions produced were slight and tenuous. The incidents concerned with in the book were far removed from the subject's own life; in her own words, she was "uninterested, yet disturbed".

However, during the reactor's reading of the two letters that had arrived that morning, gastric tone changes clearly occurred, evidently in connection with the emotions signalled. The reactor had not read the letters before, tho other members of her family had done so and had told her the main trend of the news therein, which interested and excited her considerably. This news concerned some very good fortune of her brother, the details of which she did not know until she read the letters. Figure 39 is the record obtained during the reactor's reading of the first letter. The time clock is still not working. The hunger rhythm shown in Figs. 37 and 38 had dropped out during the shock procedure, which intervened between the reading of the book and that of the letters. It had reappeared perhaps in an irregular form after the shock precedure was finished, and a suspicion of it is present at the start of this record to cast some doubt on the results obtained. The signalled "admiration" comes at the end of a rise in stomach tone, and the level is maintained for three respirations. The next signal represented "admiration with envy". It comes at a point where the level has fallen after a short

rise. Somewhat arbitrarily, the rise is correlated with admiration and the fall with envy in the entry of this reaction in the tables. The signal of "big disappointment" comes during a slight rise following a fall and followed by a further fall. As this subject, unlike Miss B., had made no attempt to mark the exact duration of her feelings, this reaction is tabulated as -, +, -. (The simpler introspective technique was used because it seemed more possible for the untrained reactor in these preliminary experiments). Whether the next signal — also "disappointment" — falls at a true rise of tone is questionable because of abdominal change. That a fall follows during the next two respirations is clear, because the abdominal and thoracic expiratory levels do not change during the second of the two respirations in question, while the stomach level continues to fall. The reaction is tabulated, therefore, as ?, -. The next reaction is thrown into the questionable class by respiratory disturbance, but a true rise of tone comes at the first signal of delight, tho it is exaggerated by a respiratory effect just at the signal. Similarly the next signal (same emotion) is clearly preceded by a large rise of tonic level, tho the state of affairs exactly at the signal is obscured. The next reaction (delight) is also obscured. The following irregularities possibly constitute hunger phenomena, and they resemble the preceding "delight rises" in a rather disquieting fashion. The final signal, given just at the end of the letter represented "much delight" and came at the end of a fall following the aforementioned irregular rises. It is a possibility that those rises were correlated with pleasant emotions that were not signalled but were summed up at the very end in an

intellectual retrospect, after the keen feelings had actually worn off. The short rise following the signal may be of some significance in this connection. However, the result is entered in the tables as the contrary one that it appears to be.

A new sort of picture is presented by the record shown in Fig. 40 (reactor K). For the first time the light was put out, the report was: "Faint preparedness — tense"; but absolutely no change in stomach level takes place. Some light may be thrown on this negative result by the first part of the record. Both times following the starting of the kymograph a drop in gastric tone takes place. Moreover, the subject reported that he became tense from the very start of the experiment. It is most probable, then, that these two decreases in tone are correlated with emotional reaction of fear or tension, which is accordingly tabulated in each case in parentheses under incidental stimuli. At the two previous places where the kymograph was started, clear fall of tone follows, with recovery, however, It was clear at that time that the experimenter was adjusting the apparatus. Now when the light was turned out there probably was no considerable increase of tenseness over what already existed, especially in view of the report of only faint preparedness. Some 20 or 25 seconds after the light is turned on, a slow recovery of tone begins, which is checked when the second turning off of the light is followed by a slight fall. The startle reaction, as usual, is obscured, but following the relighting of the light a considerable gradual rise takes place, which is tabulated as relief, parenthetized. (A rectal tracing appears in therrecord of this reactor, under the time line, but it is inadequate because enough air $^{c}$would not be forced into the balloon).

Figure 41 (same reactor) runs to within 20 seconds of the end

of the experiment. The experimenter noticed the marked tonic fall just before the end, and after the kymograph was stopped he asked the reactor whether any emotion had been experienced just previously. The subject reported rather unpleasant thinking activity, involving disappointment and angry feelings at the poor method of emotional stimulation the experimenter had tried to use toward the end of the experiment — the telling of false news, which the reactor did not believe. The reactor reported that such unpleasant, angry, critical thinking took place off and on all during the last part of the experiment, after the first attempt at falsification, and it may well be that the many not very regular tone changes appearing in that part of the record are to be correlated with the emotions experienced in the thinking. The slow undulatory rise shown in Fig. 41, before the final fall, may be of that nature. Similar cases occurred with other reactors, the experimenter noting a large tone change not falling into a prevailing rhythm, stopping the kymograph and interrogating the reactor, with positive result. However, the control procedure was not tried of stopping the kymograph after a period of no change and questioning the reactor.

The record of the final reactor, H., contains nothing of new interest except in connection with the adrenin procedure. The effects of the emotional stimulation involved in that procedure up to the time of action of the drug will now be illustrated by some sample records.

In Fig. 42 (reactor Gro.), the order of the tracings from top to bottom is: introspective signal line, time line (5 sec. intervals), rectal tracing (unsatisfactory), blood pressure (Erlanger method), abdominal pneumogram, thoracic pneumogram, gastric pressure

tracing, stimulation signal line. At the beginning of the gastric record a shallow tonus rhythm is seen. Just before the ordinate line that marks the end of the experimenter's announcement, "I want to try injection of adrenalin to-day", the tone level rises slightly, instead of falling in conformance with the tonus rhythm. The reactor reported that he was surprised at hearing the experimenter's voice, as his attention had been wandering. And because of this latter fact, he confused "adrenalin" with "apomorphine", a drug that produces vomiting, and accordingly he felt considerable apprehension. It is unfortunate that the tone fall following the stimulus is somewhat clouded by abdominal change; but because the very regular change in level does not correspond well with the abdominal shifts and because the gastric level remains low after the abdominal tracing returns to its original level, this is regarded as a case of true fall of tone. The rhythm is interrupted, its period lengthens, and then returns to normal with recovery of tonic level just before the stopping of the kymograph. The change in the blood pressure record right after the stimulus was caused by an arm movement, judging from the abrupt rise of the base line.

While the recording was suspended, final preparations were made, the reactor was given the introspection key (held in the right hand— blood pressure cuff on the left arm, injection in right arm), and he was instructed in the key's use. He was also asked whether his heart was a normally strong one, both because it is safest to make sure of that point and because the question may enhance emotional effects. The pronounced tonic fall immediately after the kymograph is restarted is quite possibly correlated with emotion. A rise in blood pressure accompanies it, and a pressure fall occurs

along with the recovery of gastric tone. The tone fall during the arm cleaning and the injection of saline solution is presumed to be associated with apprehension, tho there was no report. It seems fairly inevitable that this procedure should cause some apprehensive emotion, unless the reactor were thoroughly and recently accustomed to it. A rise of blood pressure accompanies the early part of this gastric loss of tone, a fall takes place during the actual injection, and a gradual but very considerable rise follows the injection. (The abrupt rise of pressure just following the ordinate, "Cleaned", is probably an artefact due to arm movement. The more gradual short waves represent the resultant of the well-known but mysterious Traube-Hering waves and the respiratory variations). The last pressure rise the reactor notices, expecting the adrenin effect, and he signals. The simultaneous ordinate here comes on a distinctly falling part of the gastric tracing, and again it is presumed that some apprehension was felt, at the imagined approach of the adrenin effect. The rise that precedes this portion of the tracing is presumed to be associated with relief after the injection was completed, and there is also recovery following the tone loss associated with the noticing of the blood pressure rise. All these gastric tone changes are too well correlated with the stimulating conditions to be convincingly considered as part of an independent tonus rhythm, The periods of the two waves under consideration (from trough to trough) are very long, and moreover differ from each other considerably (90 and 70 seconds). Also, a similar tho less extensive tone fall accompanies the second injection, with similar after-recovery before the adrenin takes effect.

Figure 43 is a record of reactor Gra. The rectal record

is quite satisfactory; the introspective signal line and the blood pressure tracing are not present. As for the stomach tracing, the changes during the cleaning are considered questionable. There appears to be a falling level between the cleaning and injection, with a marked rise clear at the first part of the injection. (Tube gripped by teeth at "injection complete".) A lower level prevails after the injection (saline), tonus waves appearing. The emotions recorded are all presumed. The subject reported that he "did not mind" any of the procedures. In the rectum, there is a slightly lowered level during the cleaning, with tonus rhythm unchanged. The level drops further as the shift is made to the actual injection, and the rhythm is interrupted, to return with still lowered tonic level after the completion of the injection.

In Fig. 44 is another record of the same reactor (Gra.), of different general appearance. Blood pressure tracing has been added. The record is presented without comment other than the usual abbreviations appended to it. The record of the effects produced by the drug itself is included. An abrupt fall in gastric tone, a less abrupt rectal relaxation are seen some two minutes after the injection. The blood pressure shows a preliminary fall at this point, followed by rise, with increase of heart rate. Where the blood pressure reaches a sustained high level, the reactor signals that he feels the effects of the drug (by saying "Now", in accordance with previous instructions). A further fall in gastric tone has occurred. The drug effects will receive no further discussion in this paper.

Fig. 45, reactor Miss G. shows a few interesting positive results. The stomach waves at the beginning of the record may

represent a hunger rhythm — $1\frac{1}{2}$ hours after breakfast. The continued rise just before the signalled end of the announcement may be associated with the attention process. The experimenter's announcement was: "I am going to try a hypodermic injection", no mention being made of adrenin. The reactor doubted this statement, and there is no immediate change of level. (A forced expiration takes place, however). There follows a gradual rise of tone, with the tonus waves absent. When the table is brought out, there is a prominent fall, followed by recovery and then an abrupt fall, these changes corresponding with the report: "Wondering, then worried when saw syringe." Because the second tone drop came right after a deep inspiration with large increase of pressure on the gastric balloon, and because the same combination occurred several times in this experiment, the possibility was considered that the drop was an artefact due to a small leak in the balloon. Against this possibility it can be argued that the fall does not take place after every large increase in pressure (e.g. in Fig. 45, after the announcement), and that there is no gradual fall in level taking place over the whole course of the experiment. To check this factor, the experimenter asked the subject to take a very deep breath. The record of this control procedure is shown in Fig.46, and presents no fall in level following the very deep respiratory effort. It is probable, therefore, that the deep breaths followed by fall in gastric level are true sighs, associated with unpleasant emotion.

Fig. 47, same reactor, shows what took place during the injection of adrenalin. The saline injection had already taken place, and the reactor had recognized it as a control. This time she was

worried when she saw the suprarenalin bottle, and signalled. The signal is preceded by a rising level, during the cleaning of the arm — possibly a nerving up effect. A short abrupt fall occurs just at the signal, followed by a further fall after the cleaning, then recovery, then fall as injection approaches. The changes when pain is signalled are questionable. We find a drop at the signal: "Worried at spread of [local] effects." The rest of the record shows the beginning of the drug effect, the reactor signalling when she felt the heart symptoms.

Fig. 48 is from the record of reactor H. During the cleaning procedure he objected to the method used — objection not expressed at the time. The marked tonic rise toward the end of that procedure may be associated with the emotional content of the objection. The emotional reaction called forth by the actual injection was mild irritation at what the reactor considered a poor technique. The gastric tone level falls slightly during the injection. In the rectum (uppermost tracing) spontaneous rhythmic changes precede, so that it is more questionable whether the tonic contraction toward the end of the cleaning is associated specifically with the emotion felt — tho the rectal change corresponds well with the gastric, with no change in abdominal level. The injection puts an end to the tonus rhythm, and the level is lowered. It is probable that there was some fear involved at this stage, as well as the irritation.

Before discussion of the tables, presentation of a duodenal record is desirable — Fig. 49, reactor R., pistol threat procedure, abdominal tracing above, chest in the middle, duodenal below. It shows the irregular nature of the duodenal hunger rhythms and the

abolition of the latter by effective emotional stimulation, with lowering of level, and recovery following. The procedure here was carried out in the light. The pistol shot had previously been used in the dark, so that the subject knew that the pistol was real; and tho it was not working now, he reported fright. Twice with the procedure of turning off the light, negative results were obtained— no appreciable tone change. The introspective report was "Cringed a little — scared of what might come" — apparently less intense emotion than "fright" with the pistol threat.— The results of this single successful duodenal experiment have been entered in the gastric tables. They include but four stimulations (twice the light, once each the pistol threat and the rat), and in each case the result has been marked in the detail table with an asterisk, to distinguish it from the stomach results.

## 2. The Tables of Results.

In the detail tables (Table 1, stomach; Table 4, rectum) the attempt has been made to present in abbreviated notation all the results of the experiments concerning the gastro-intestinal tonic reactions to emotional stimulation. Then in the summarizing tables these results have been summarized in a statistical way (Tables 2 and 3, stomach; Table 5, rectum).

### a. The Detail Tables.

During the discussion of the records a start has been made toward showing how the detail tables are compiled from the kymograph records. The meaning of the notation will now be summed up.

In Tables 1 and 4, it will be seen, the reactors are listed

down the left-hand side and the stimulation procedures across the top. For each reactor, then, the reactions are entered in a single horizontal row, under the appropriate stimulation procedures. Each of the major horizontal rows consists of three horizontal lines. In the uppermost of these lines are entered the changes in tonic level: + indicating increase of tone (contraction of the organ), - indicating decrease of tone (relaxation), 0 no change, ? indeterminate reaction. In the lowest line are entered in abbreviation the emotional reactions which are associated with the tonic changes represented in the uppermost line. The key to the abbreviations of emotions will be found on the summarizing tables. In the intermediate line are entered changes in "automatic" tonus rhythm, when such changes occur, + indicating increase in the depth of the waves or a starting up of rhythm, - indicating decrease of depth or dropping out of the rhythm.

In the tabulating of the emotions, the abbreviation when not parenthetized indicates an emotion that was actually reported by the reactor, but when parenthetized, one that was not reported but is presumed by the experimenter to have been present. In most cases a single emotion is tabulated, spaced off from other emotional reactions; but in some cases two or three are entered together, when they are reported as occurring together. For example, in Table 1 see FT reaction of Miss C. to pistol procedure, and Miss B.'s reaction to snake.

As for the tabulation of the tonic changes, level or rhythm, a single figure indicates the change that took place upon the presentation of a stimulus or at the appearance of the tabulated emotional state. Where, however, two figures occur in unspaced and unpunctuated

succession, associated vertically in the table with a single emotion or complex state (e.g. in Table 1, first reaction of Gra., first of B.), then the first figure denotes the change that occurred upon presentation of the stimulus or at the appearance of the emotional state, the second the change upon removal of stimulus or disappearance of emotion in question. When several distinct emotional reactions occur successively between application and removal of stimulus, then the convention has rather been to connect the tone change upon removal of stimulus with a separate emotional designation of relief. This would naturally be the case in connection with the more complicated stimulation procedures, and in the cases where the pistol shot intervened in the light stimulus. This latter convention has also been used when the tone change upon removal of stimulus has been delayed, as in the case of reactor K. with light stimulus; so that the other convention of two tone-change designations with a single emotional abbreviation is used only when the two respective tone changes are associated quite clearly with the presentation and removal of stimulus and the appearance and disappearance of the emotional state.

If, now, in connection with one emotional state there are entered two or three tone-change designations separated by commas, then the changes are all associated with the appearance or presence of the emotion and none with its disappearance. See for example in rectal table (Table 4) the first reaction of B. The emotional state is a mixture of fear and wondering. In the rectum there is first a fall of tone, then a rise. The fall upon removal of stimulation is classed separately as Rl. (See Fig. 25). Sim-

ilarly, in Table 1, reactor Miss G., reading procedure, there appears in connection with disappointment (Dpt) the tone change designation -, +, -. This has been discussed above in connection with Fig. 39. Just before this entry is one in which a comma appears between two emotional designations. The insertion of this comma was a very conjectural matter, the investigator considering the possibility that the first tone change was associated with admiration, the second with envy, the two emotions occurring, or at least starting, serially, tho they were reported as "Admiration with envy". A similar liberty was taken with the final reaction of reactor K under announcement procedure, the reaction that forms the subject matter of Fig. 41.

For Miss C., under "Odors", there are two triple tone-change designations appearing. There being no commas, the first figure indicates the change at start of stimulation, ~~the final figure indicates the change at start of stimulation~~, the final figure the change upon removal of stimulus. The middle figure, then, represents a change taking place some time during the stimulation.

The use of brackets, [ ], in designating some of the tone changes of the rectum has been mentioned in the discussion of records. [+,-] means a contraction followed at once by relaxation to original level; [-,+], similarly, a relaxation followed by recovery to original level. This additional convention was introduced because this seemed in the rectum quite a distinct kind of reaction, especially in connection with startle, but notably in the case of reactor R, in connection with disgust at the odor of decay (Table 4). When the odor was presented, the rectum shows

a rapid contraction [+,-], then a relaxation [-,+]. The same reaction occurred the first time the nose was touched, with only the contraction at the next two touch procedures. The possibility of artefact, however, is not entirely ruled out here. In the statistical summing up, a bracket is considered as but one reaction — contraction or relaxation, as the case may be. Apart from the brackets, each tone-change figure is considered a separate reaction or result.

### b. The Summarizing Tables.

From the results listed in the detail tables, the statistical summarizing tables were constructed. There are two of these tables for the stomach, Table 2 summarizing the results by reactors, Table 3 by stimulation procedures. Table 5, for the rectum, summarizes by reactors.

In Table 2 the reactors are listed across the top, the emotions down the left side. For each reactor the reactions are classified as positive, contrary, negative, or indeterminate, designated by the initials P, C, N, and I. For all the emotions, of course, a 0 reaction is classed as negative, a ? as indeterminate. In the case of the heading "No emotion", a 0 reaction is a positive result, either a + or a - in the detail table is a negative result. For each of the actual emotions, however, a working hypothesis is necessary as a basis for deciding whether a + or - tone-change is to be provisionally considered a positive result, leaving the other to be classed as contrary. In accordance with the expectations mentioned in the introduction, for the pleasant "emotions" (from

pleasantness to appreciation in the table) + is considered the characteristic positive result, and - therefore the contrary. Similarly we should expect to find - as the positive result for the "unpleasant" emotions. But such a simple hypothetization has been amended empirically and theoretically to such an extent that only in the case of fear, envy, disappointment, irritation, pain, and unpleasantness does loss of tone figure in the table as the positive result. In the case of disgust, startle, and surprise, it became clear empirically early in the experiments that the predominant tone-change was +. In the case of tension and wonder, + was decided on because it was the first reaction met with and seemed so conveniently to distinguish these states from fear. That this provisional guess was wrong, was shown in the complete results. In the case of "objection", the single reaction met with was +. But the very classification "nerving", however, and its characterization as + were hardly empirical matters, but rather theoretical necessities arising from contrary results in fear-producing situations. The introspective report "Keyed-up", which served as the empirical basis for this classification, might perhaps have been as well rendered "tension" as "nerving". The full discussion of the reasons for this invoking of the theorist's license must still be postponed for awhile. The selection of + as the positive result for anger is also theoretical; empirical evidence here was deficient in the experiments. The key to this theorization is to be found in the opposite effects on behavior of the two emotions, fear and anger. Allied, but slightly more empirical, is the + for resistance. These matters will become clearer later on, in the discussion of the theory of compensating reactions. We would expect a component of anger in irritation, but the single empirical result with the latter was loss

of tone. — It will be seen that the tone-change which in constructing the summarizing tables is considered a positive result is entered in Table 2 between each emotion and its abbreviation. It is omitted in the case of those emotions with which were associated only negative or indeterminate results. The abbreviations of the emotions are for convenience repeated across the table.

A word more about the entry of results in the summarizing tables. If - is a positive result at the appearance of fear, + is the positive result at its disappearance. Thus the reaction $\overset{-\,+}{F}$ represents two positive fear results. This is the logical interpretation, as the rise of tone at removal of stimulus is confirmation of the association of - with the fear reaction. This, of course, holds for all the emotions. For instance, $\overset{-\,+}{T}$ is entered as two contrary results under tenseness.0 and ? do not change their significance when associated with removal of stimulus. When two or more emotions occur in one reaction, associated with but one tone change, the tone change is classed in the summarizing tables with only one of the emotions, the one first reported or otherwise most prominent.— The changes of tonic rhythm do not figure in the summarizing tables.

In Table 2, now, the results for each reactor are summed up at the bottom, and the results for each emotion with all reactors are summarized at the right. It is this latter summary that will now be discussed. For *fear*, *disgust*, *unpleasantness*, *pleasantness*, *relief*, the results are predominantly positive— that is, the number of positive results very substantially overbalances the total of contrary and negative together. The indeterminate reactions are left out of of consideration in this statement. They are included only to show

the relative difficulty of obtaining clear-cut results, because of respiratory interference, etc. The positive margin is disappointingly absent in the case of *amusement*, and for *delight*, *admiration*, *appreciation*, *disappointment*, and *surprise* it must not be correspondingly relied upon, on account of the sparsity of observations. In the case of *"No emotion"*, the positive results predominate, but the number of negative results is high, possibly because of poor introspective technique. The results under "*attention*" will be considered later. That "*nerving up*"should give such a positive preponderance is not surprising, because "the dice were loaded" in this case: only apparent tonic rises at appropriate stimulations were so labeled, some of them turning out indeterminate. In the case of *startle*, there is no preponderance, but for *wonder* and *tenseness* the contrary results are in overwhelming majority. The first guess was wrong, and in final summing up positive and contrary for these two states must be interchanged.

The results for all emotions with all reactors are summed up at the bottom of this part of the table. It will be well to correct this summary by omitting the figures for *attention* and revising the results for *wonder* and *tenseness* as suggested above. The corrected totals for P, C, N, and I respectively will then be: 253, 42, 51, 130. The indeterminate results amount to roughly 1/2 of the positive, the contrary and negative to roughly 1/6 and 1/5 respectively.

However, lest the practice of including reactions with emotional accompaniments presumed by the experimenter should have led to a real error in these results, it was considered advisable to make a summary including only the non-parenthetized reactions. Such a summary is presented at the extreme right of Table 2, with revised

figures for only those emotions which were represented in the first summary by some parenthetized reactions. The positive predominance quite significantly remains, tho it is reduced in the case of fear, less reduced for unpleasantness. In the grand total of non-parenthetized reactions, at the very bottom of the summary for all reactors, the figures must again be corrected for attention and wonder and tenseness, and then become 154, 39, 42, 107, with the indeterminate results about 2/3 the positive, the contrary and negative each roughly 1/4. It appears, therefore, that the inclusion of parenthetized reactions did exaggerate the positiveness of the results, but the predominance of the positive results still remains after the correction.

It may be mentioned that the incidence of indeterminate reactions shows that respiratory disturbance was most frequent in the case of startle and of amusement, as might be expected, less frequent in disgust, unpleasantness, and fear. Again, as might be expected, relief is most free from respiratory disturbance.— The separate summaries for the individual reactors show the differences in the results with the various subjects. (The figures should be corrected, as above, for wonder, tenseness, and attention). The positive margin is greatest for Gro., Gra., and Miss B., least for reactor B. The results with Miss G. are marked by the large number of negatives, as are also those with reactors R. and B. Miss L. is notable for contrary results; R., Miss C., B., K., and H. for indeterminates— considerable respiratory disturbance.

Table 3 is altogether similar to Table 2, except that the summary is made by stimulation procedures instead of by reactors. There is here brought out what were the chief emotional states obtained with each procedure, and also, in the summing up, differences

in the results with the different procedures. Correction must again be made for wonder, tenseness and attention, the correction being most considerable for the light procedure, because of the large number of reactions of wonder and tenseness. The positive margin is safe for nearly all of the procedures, with odors and reading falling behind, and also incidentals if only non-parenthetized reactions are considered. The use of the rat was not a satisfactory procedure.

Table 5, the summarizing table for the rectum, is entirely similar to Table 2, but is comfortably shorter. For the different emotions the same tone-changes are considered positive results as in the case of the stomach. It will be seen in the final summary that tho the positive results have a plurality of reactions (not counting the indeterminates) they no longer overbalance the combination of contraries and negatives. As compared with the stomach results, the proportion of total reactions represented by negative or indeterminate results has changed but little; it is the contrary results which have gained, at the expense of the positive. In this way the positive margin seen in the stomach has been wiped out for fear, disgust, and unpleasantness, also for tenseness. For relief, a pleasant state, it has to a certain extent remained. As before, startle shows no positive margin, and the results with amusement are disappointing. It might be expected that disgust, as an unpleasant emotion, should show a predominance of minus reactions in the rectum, with the vomiting reaction absent, but such is not the case. Parenthetized nerving reactions were not recorded for the rectum, with one exception. Instead, these reactions were tabulated as contrary fear reactions (parenthetized). It might be thought that this

would account for the gain of contrary reactions in the case of fear. But the gain exists also for the non-parenthetized reactions; and also if the same shift in the tabulation of (Ne) reactions were made in the case of the stomach, no such large proportionate gain of the contraries would result. This gain, then, in the case of the rectum is not an artificial matter.— The feature of the results with the rectum, then, as compared with the stomach, is the irregularity of the direction of tonic response. The number of contrary results is about 5/7 that of positive ones, as compared with 1/6 to 1/4 in the stomach.

Turning for a moment to the separate summaries for the individual reactors in this table, it may be of interest that in the case of Gro. and Gra. the positive results still outnumber the contraries by a considerable margin. For Gro. there is a marked gain in negative reactions, as compared with the stomach results for this reactor; in B. there is a marked falling off of the negatives. In Gra. the rectal records were unusually difficult to interpret— there is a large increase of indeterminate responses.

### 3. Interpretation of Results.

Because negative and contrary results have been found in not negligible numbers, are we for that reason to conclude that tone changes in the gastro-intestinal walls are not factors in emotional states, psychologically-speaking, but merely physiological by-products, more or less capricious, not contributing to emotional drive and emotional content? Because of the clear preponderance on the whole of positive results in the stomach, the clearly positive records of reactor Gro., and the large positive statistical preponderance of results in the cases of Gra. and Miss B. despite the

irregular appearance of their records — because of these features of the evidence the writer is reluctant to believe that any such negative conclusion is forced upon us by the occurrence of negative and contrary results. There are still other difficulties appearing in these experiments, that are in the way of the visceral theory of the emotions as regards the alimentary canal — the question of the time factor, and the problem offered by the rhythmic tone changes; but meanwhile how are the negative and contrary results to be explained?

### a. The Negative Results.

One class of negative results consists of the negative "No" reactions, cases where there is definite tone change but the reactor reports that no emotion occurred or was felt. Six of these cases occurred with Miss G., one with reactor Gro. The case with the latter took place when the use of the rectal balloon was announced. A fall of tone in the stomach ensued, as clear as any of the changes with this reactor, but the subject said later that he "did not mind" the announcement. It seems most probable, however, that some unpleasantness was felt, though the reactor realized the reasonableness of the rectal balloon's use and "did not mind". Such a report might cover a multitude of emotional states. A similar case is that of Miss G., mentioned previously, where the report was "No effect — I assumed composure". If it was necessary to assume composure, it is probable there was some effect. It is possible that the other cases with this reactor are due to difficulties in the introspective technique — desire not to feel or show emotion, or shift of attention.

Of the other negative reactions, those in which emotion

was reported but no tone change is found, it is possible that some could be accounted for on the basis of the low intensity of emotion involved. This might particularly be true of the negative reactions of Miss G. with the reading procedure — pity and disturbedness are two emotional states in point. There are two possibilities in this connection: either in weaker emotions the tone changes are too small to be registered with our gross method, though large enough to affect receptors; or the stomach and intestines are affected in and contribute to only the stronger emotions, leaving the weaker ones to be accounted for solely by changes in other organs, perhaps largely vascular, which probably contribute to the more intense emotional states as well.

We would hardly expect negative results in the stomach in connection with disgust when that emotion is considerable, and yet such results occur (see Fig. 35). It must in this connection be remembered that mere unpleasantness, not involving disgust, was found in the experiments to be associated with decreased tone of the stomach, the effect opposite to that associated with disgust. It is not improbable that the negative disgust results are due to a combination of both disgust and unpleasantness effects, in balancing amounts so far as intragastric pressure is concerned. For this explanation, to be sure, the two effects, contraction and relaxation, must be occurring in two different axes of the stomach, in two different groups or layers of muscle fibers, or in different parts, as Cannon observed them in the case of vomiting.

However, in general, truly negative results in one organ in certain cases cannot in themselves dispose of the visceral theory.

There always remains the possibility that other organs are contributing mainly to the emotional state, in which case, however, we should expect the state to differ somewhat qualitatively from what it is when the first organ in question is involved. As a preliminary and limited test of this possibility of "another organ", the simultaneously secured gastric and rectal records were compared, to determine whether negative reactions tended to occur in both together or in each separately. Leaving out of consideration the cases in which the tone change of one of the organs is questionable, there are altogether 19 cases in which either of the organs gave a negative result. In only 3 of these are both negative; in 7 the stomach alone shows a negative result, in 9 the rectum alone. Thus the negative results apparently tend to occur in each organ separately rather than in both together; if the one is not making an alimentary canal contribution to the emotional state in question, the other is. On this basis, too, it is probable that this alimentary canal contribution is not a specific part of each emotional state, differing for different emotions, but is rather a general contribution in the nature of affective tone or feeling tone (pleasantness and unpleasantness). This view,already proposed in the introduction, will be considered again after the following discussion of the contrary result.

### b. The Contrary Results - Theory of Compensating Emotional Reactions.

For the contrary results in the case of the pleasant emotions no theoretical explanation can be offered. There were none for pleasantness, and perhaps the proportion would be reduced for amusement and delight if these emotions could be easily enough stimulated to get much more data. That is the best that can be

said for them. For relief the number of contraries is reduced by about half for both stomach and rectum, when it is seen that nearly half of these contraries (tonic falls) follow tonic rises (in some cases contraries) in connection with unpleasant emotions; that is, in these cases relief from the emotional state is marked by a change opposite to that associated with the state itself - a positive result, or if contrary, to be explained by explanation of the contrary result with the preceding emotional state.

The contrary results in the stomach for disgust and unpleasantness may perhaps be explained on the basis of the opposed tonic effects of these two emotions there. For such an explanation it must be assumed that in the contrary cases the tonic changes involved in both of these emotions are present in the stomach (cf. the presence of both effects in vomiting). The one effect prevails as far as intragastric pressure is concerned, the other prevails as regards attention and consciousness — the "final common paths" and the reactions of the subject. It is of interest in this connection that all of the contrary results for unpleasantness occurred with the use of the presumably disgusting odors as stimuli; two of the three disgust contraries occurred with the odors, one with the snake, in which case fear (opposite tone change to disgust) was also reported at a slightly different time in the stimulation. In the case of Miss B., with the snake, unpleasantness, apprehension, and disgust were reported as one emotional state, marked by fall in pressure.

For a possible explanation of the contrary fear reactions we must go farther afield. Upon meeting the idea that in fear the sympathetic division of the autonomic nervous system is

in action, one is struck by an apparent contradiction — namely, the well known defecation reaction that occurs not infrequently in fear and fright. For defacation is brought about thru the sacral autonomic system, which produces increased tone in colon and rectum, as opposed to decreased tone thru the sympathetic division. However, the defecation reaction seems to appear when the fear emotion is successfully combatted and the individual is able to carry on in spite of the emotion. The theory therefore suggests itself that the defecation reaction represents a compensating mechanism; and in short the attempt is made to explain the present contrary results for fear in the same way.

The theory, in simple form, is this: Action of the sympathetic system in general produces bodily changes (decrease of muscular tone of the alimentary canal, certain vasoconstrictions and dilations) which thru stimulation of internal receptors set up afferent impulses that, in playing upon the central mechanism, cause unpleasant feeling-tone, or, in terms of behavior, avoidance of the situation that sets the sympathetic system into action. Activity of the parasympathetic produces different bodily changes (increase of alimentary muscular tone, certain other vaso-dilations), setting up afferent impulses that cause pleasant feeling-tone and behavior of seeking continuance of the situation which has set up the parasympathetic reaction. The emotion of fear consists essentially of a group of bodily changes produced by the sympathetic system, causing unpleasant feeling-tone and the tendency to avoid the fear-inspiring situation. What happens when the individual carries on in spite of strong fear, managing not to avoid the stimulating situation, is that thru the saying of encouraging

utterances ("I can do it", "I will do it", "It's not so hard") or thru joking or thru some other stimulation, the parasympathetic system is thrown into control of some organ or organs, furnishing afferent stimulation that produces pleasant feeling tone and the ability to continue on the course of action that originally called out the fear. The defecation reaction in fear may be caused by such a compensating mechanism, and it is possible that the contrary results for fear in stomach and rectum in the present experiments could be thus explained.

That is the reason for the emphasis laid on the emotion "nerving" in the making of the tables. "Nerving" is a convenient and descriptive name for the compensating emotional effect just discussed. The contrary results in the rectum for unpleasantness (perhaps to some extent in the stomach as well) may also be based on the compensating mechanism. The same argument that was used in the case of fear will hold for unpleasantness; fear did not figure mainly as fear, but by virtue of its nature as sympathetic autonomic effect with unpleasant feeling-tone. Unpleasantness (as emotion) must also be thought of as sympathetic effect— e.g., decreased tone in the stomach. Whether fear differs from mere unpleasant emotion only in degree or in the inclusion of other organs or of ideational (striped muscular) factors, cannot be guessed at with any probability as yet.

It should be mentioned here that the present experiments offer good conditions for meeting with the compensating reactions, if these are a reality. For the reactor is determined to go thru with the experiment and also knows intellectually that nothing truly injurious is going to happen. That is, conditions are right for his

being able to compensate for unpleasant and fearful emotions when necessary. When we do get the sympathetic effects in these unpleasant emotions, which is predominantly the case in the stomach, it must be either that the unpleasant emotional effects thru the body as a whole are not extensive enough to require compensation — that is, there are already present in the various organs sufficient emotional effects with pleasant feeling-tone associated with interest or determination or pride or the like, to overbalance the avoidance tendency of the new emotion; or else the compensating reaction, when necessary, is taking place in some organ or organs other than the one in question. According to the larger proportion of contrary results in the rectum, it would seem that the rectum is more often than the stomach the seat of the compensating reactions. In the records of Gro. and Gra. (Figs. 14, 16, 17, 20, 24) are several places where loss of tone in the stomach is accompanied by increase of tone in the rectum. In Fig. 25, reactor B., we have the same effect at the second stimulus, just the reverse at the first — the compensating reaction in the stomach. It is altogether possible that various parts of the vascular system should also exhibit compensating reactions.

And it is not necessary to have first the extreme fear reaction and then the compensating reaction as a secondary effect. It should be possible that the individual's preliminary attitude would set up the compensating reaction along with the general fear reaction — a habit-formed short cut.

After this discussion of the theory of compensating emotional reactions, we can take up in terms of it certain loose ends left in the tabulated results. In the case of disgust, for

the rectum there are tabulated six compensating reactions, four unpleasant effects. For wonder and tenseness the stomach shows a great majority of fear-unpleasant effects, with one compensating reaction for each. In the case of startle, both effects are evenly balanced in both organs. This would depend upon the occurrence of some fright and its compensation sometimes in stomach, sometimes in rectum, sometimes elsewhere. For pain, the meager results show two compensating reactions in the stomach, one unpleasant effect in rectum (see Fig. 44). The writer would rather expect to find anger marked by rise of tone in stomach and rectum, hence his interpretation of Fig. 41, reactor K. For anger seems to be largely a compensating emotion — the avoiding effects of fear and unpleasant emotion are largely compensated in anger. It is probable that the compensating effects here occur also or mainly in other organs, especially in parts of the vascular system. Cannon, to be sure, found stoppage of gastro-intestinal movements in enraged cats.

Just what may be the significance of the "attention rise" in the stomach is hard to say. To see whether there really was such an effect, both rectal and stomach records were carefully combed for tabulation of all tonic changes taking place when the reactor was addressed by the experimenter. For the rectum the totals for P, C, N, and I become 3, 3, 3, 3 — certainly no decided effect. For the stomach, contrary effects are decidedly lacking. The totals are 23, 2, 15, 13. Rise in tone certainly takes place much more often than fall. Whether this rise indicates a compensating effect for unpleasant emotion due to disturbance of the reactor's peaceful state or a pleasant emotion due to anticipation of something interesting to interrupt the boredom, one can hardly say.

We return now to the view mentioned in the introduction and at the end of the discussion of negative results. Apart from the action of the stomach in disgust, the results of the experiments show nothing to indicate that the specificity of each emotion (fear, tension, wonder, irritation, pleasantness, amusement, delight) depends on its gastro-intestinal components. It would seem rather that the muscular wall of the gastro-intestinal organs contributes merely a certain amount of feeling tone to the emotional states. It may be that more extended work on stomach and rectum together, on duodenum and rectum together, if not on all three at the same time, would show the different organs to enter in different degrees in the various emotions. Until then the writer would look for the specificity of emotions to the locus of incidence of the vascular factors and to striated muscular factors.

### c. The Time Factor

A very important factor as regards the James-Lange theory is the test as to whether the bodily changes in question precede the feeling of emotion. Cannon and Washburn, as already mentioned, were able to show that the start of the "hunger contractions" of the stomach always preceded the feeling of hunger pang as signalled by the subject. No such regular relationship was shown in the present experiments on emotions in the few cases where the introspective signal was used. In a few places the necessary time relationship does appear nicely (Figs. 31, 36, 39). In all probability the situation here is much more complex than in the case of the hunger pang. If the stomach is merely one of a number of contributors to the emotional complex, it may well be that the other contributing changes are occurring at slightly different

times. The gastric factor does not seem to be isolable on the introspective side, as it is in the case of the hunger pang. The requisite for a fairer test is the taking of simultaneous satisfactory records from gastro-intestinal system and vascular system.

### d. Tonus Rhythms.

A rather difficult point for the visceral theory is offered by the rhythmic tone changes (tonus waves) that are so clearly shown in some of the experiments (Fig. 37, Fig. 14). These are often larger than the changes that seem to be correlated with emotions, and yet they are not felt as emotion— not even as hunger until they reach a very large amplitude. If, then, the "emotional" changes are to be felt as emotion, they must in some way be different in kind from the rhythmic contractions. They must take place in a functionally different group of muscle fibers (cf. circular, longitudinal, and oblique fibers in the stomach), or in some other way result in a different kind of deformation of the organ in question— perhaps thru the way in which the various muscle layers cooperate.

## IV. Conclusion.

Tonus changes of stomach and rectum in emotions are indicated by the experiments with the balloon method described in the first part of this paper. The specificity of the changes appears limited to differentiation between pleasant and unpleasant emotions, with the exception of a possible specific effect in the stomach in the case of disgust.

The attempt was made to explain certain negative and contrary results that occurred. The latter were interpreted on the basis of a theory of compensating emotional reactions, suggested by the defecation reaction that is known to occur occasionally in fear or fright.

These preliminary experiments cannot yet indicate, however, whether gastro-intestinal tone changes are felt as emotion and therefore cannot in general give indication as to the truth of the James-Lange theory of emotions.

## Legends to Figures.

Fig. 1 Rectal Tube and Balloon (see text)

Fig. 2 Rectal System (see text)

Fig. 3 Gastric System (see text)

Fig. 4 Connections of Measuring Manometer.

R signifies "to rectum balloon"; S, "to stomach balloon"; $I_R$, "to rectal system's intermediate chamber"; $I_S$, "to intermediate chamber of stomach system"; Infl are the respective inflation openings; Y, glass Y-tubes; P, pinch cocks ($P_S$ closed, $P_R$ hanging free, to leave rubber tube open); M, water manometer of 5 mm. bore and 18 cm. arm length; Sc, millimeter scale.

Fig. 5 Thoracic Pneumograph (see text)

Fig. 6 Photograph of Apparatus (see text)

Fig. 7 Erlanger Method for Continuous Recording of Blood Pressure (see text)

Fig. 8 Fluoroscopic Configurations of Duodenal Tube (see text)

Fig. 9 In this figure and all of the kymographic records following, the meaning of the notation at the side, labelling the separate tracing lines, is as follows, in the order in which they occur from top to bottom:

I: Introspective signal
T: Time in 5 seconds
R: Rectum
BP: Blood pressure
Ab: Abdominal pneumograph
Th: Thoracic pneumograph
St: Stomach

D: Duodenum

Si: Stimulus signal

In this figure, v denotes the voluntary production of the chest movement (see text).

Fig. 10. v, as in Fig. 9: voluntary production of chest expansion. In c, careful measurement showed artefact. The dots on the abdominal and gastric tracings, respectively, show corresponding points. Gastric level fell where abdominal girth decreased, rose where the latter increased.

Fig. 11. Rectum controls (see text). C and R on the signal line refer to contraction and relaxation, respectively, of anal muscles.

Fig. 12. Rectum controls (see text). c and r as in Fig. 11.

Fig. 13. Rectum controls (see text). Order of tracings, and abbreviations c and r, as in Fig. 12.

Fig. 14. For meaning of abbreviations at top and bottom, in this and all succeeding figures, see text.

Fig. 16. Order of tracings as in Fig. 15.

Fig. 17. Tracings as in Fig. 15.

Fig. 18. Tracings as in Fig. 15.

Fig. 19. Same order of tracings.

Fig. 20. Same order of tracings.

Fig. 21. Same order of tracings.

Fig. 22. Tracings still as in Fig. 15.

Fig. 23. Tracings the same.

Fig. 24. Same order of tracings.

Fig. 36. Order of tracings, top to bottom: Introspective signal, time (clock

not working), abdominal pneumograph, thoracic pneumograph, stomach, stimulation signal.

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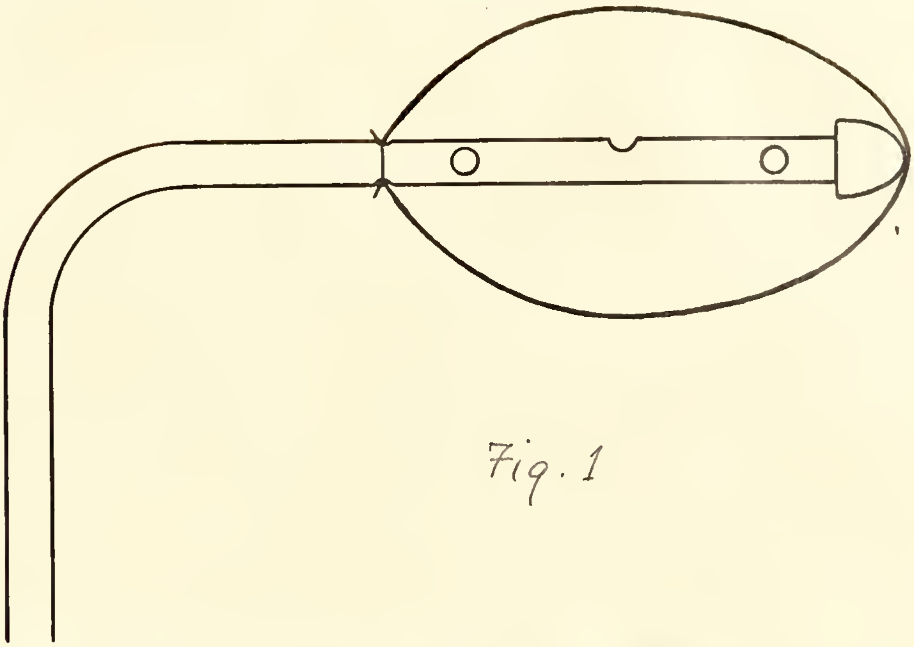

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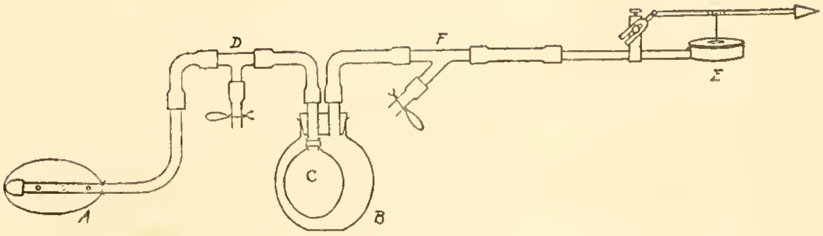
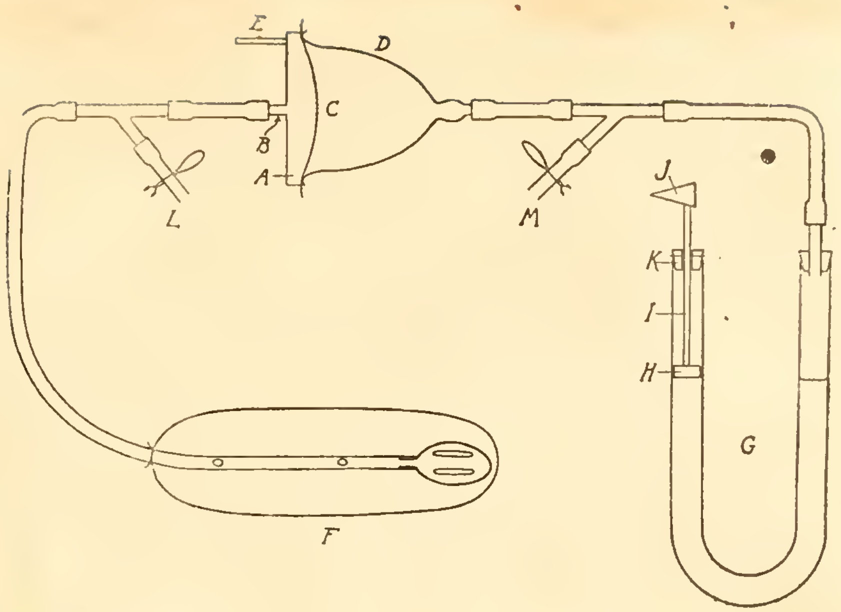


Fig. 2



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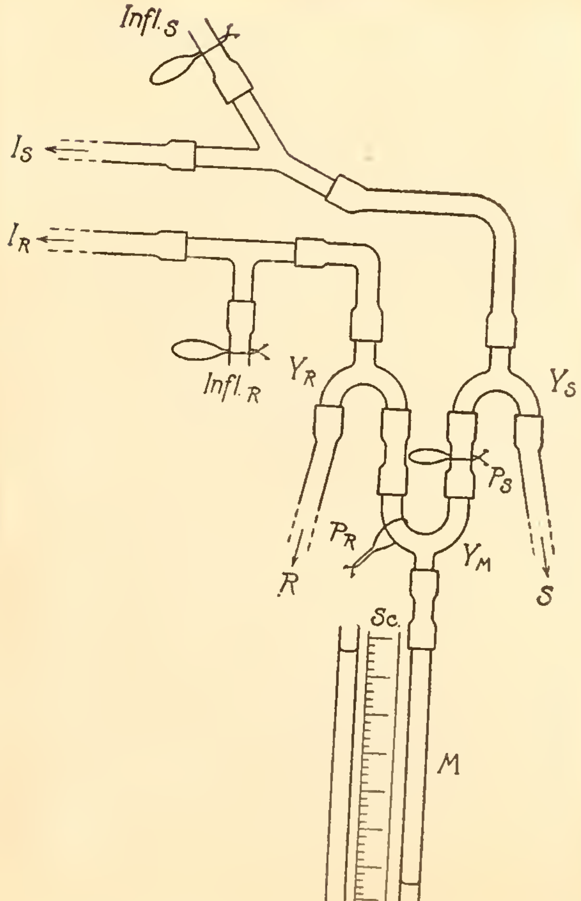

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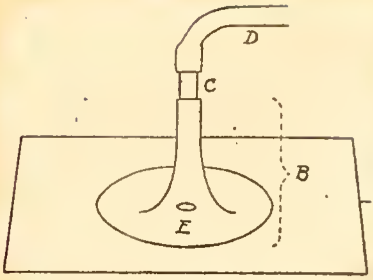

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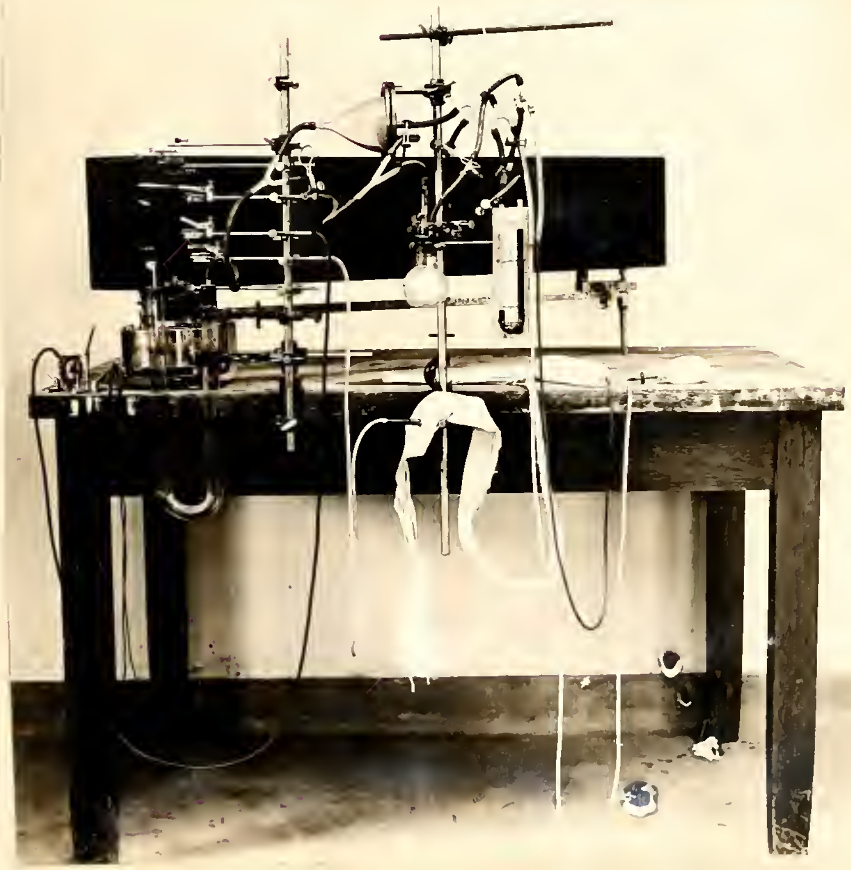

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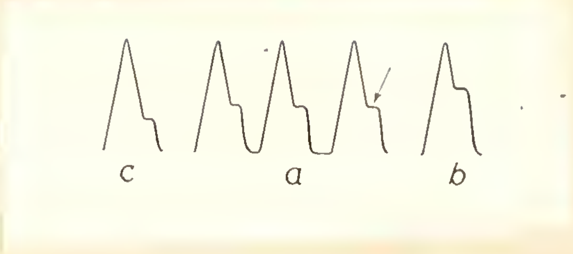
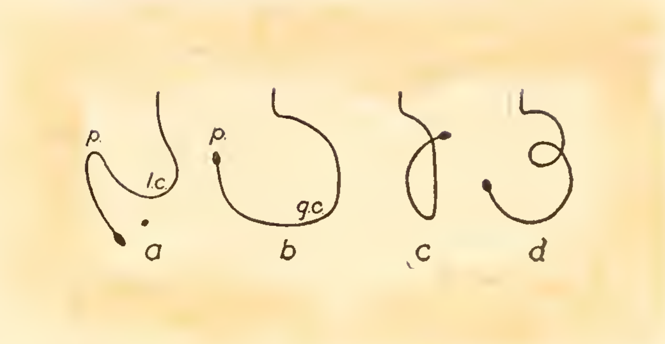


Fig. 7



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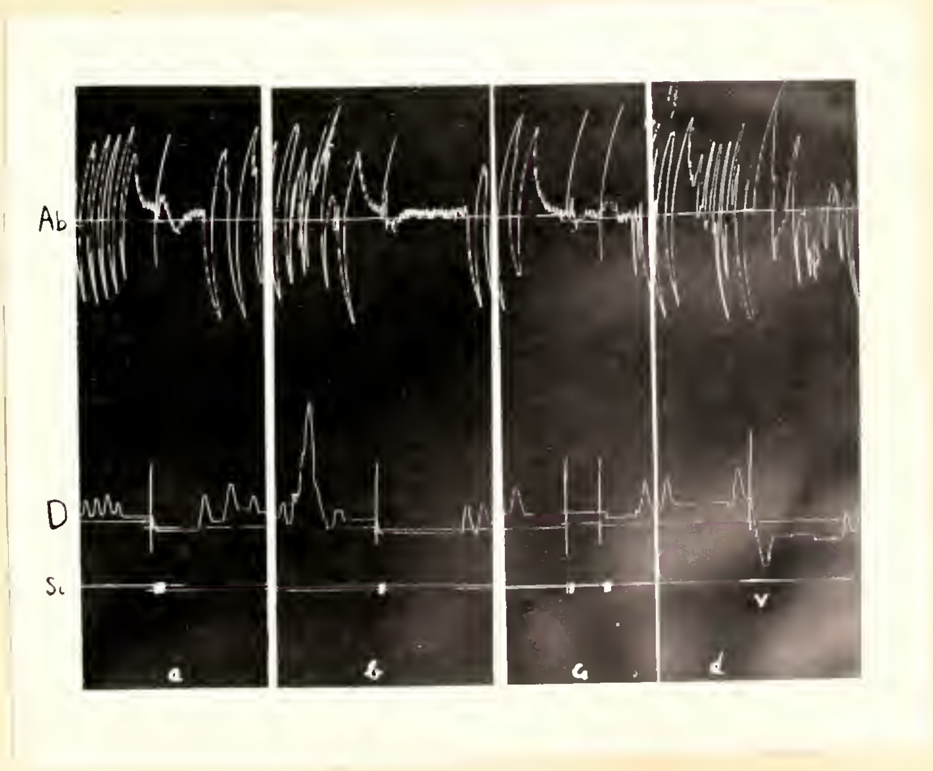

Fig. 9

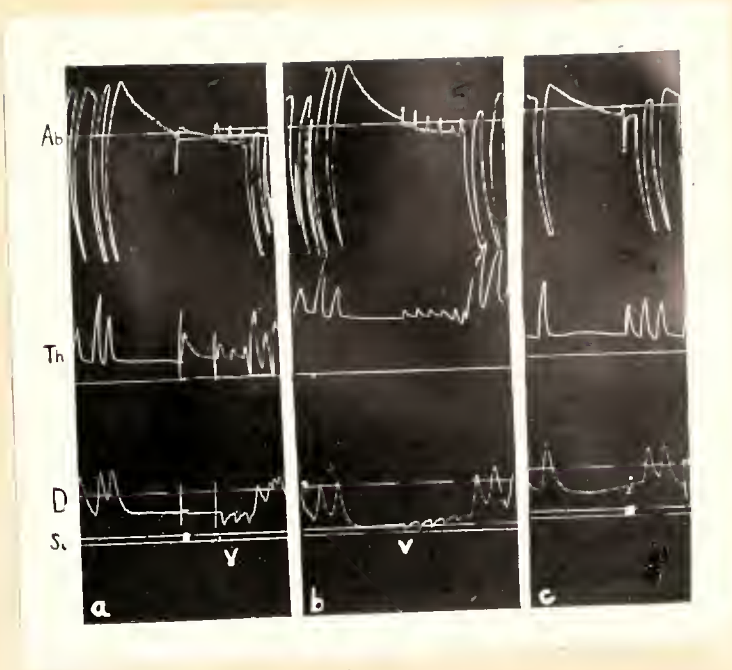
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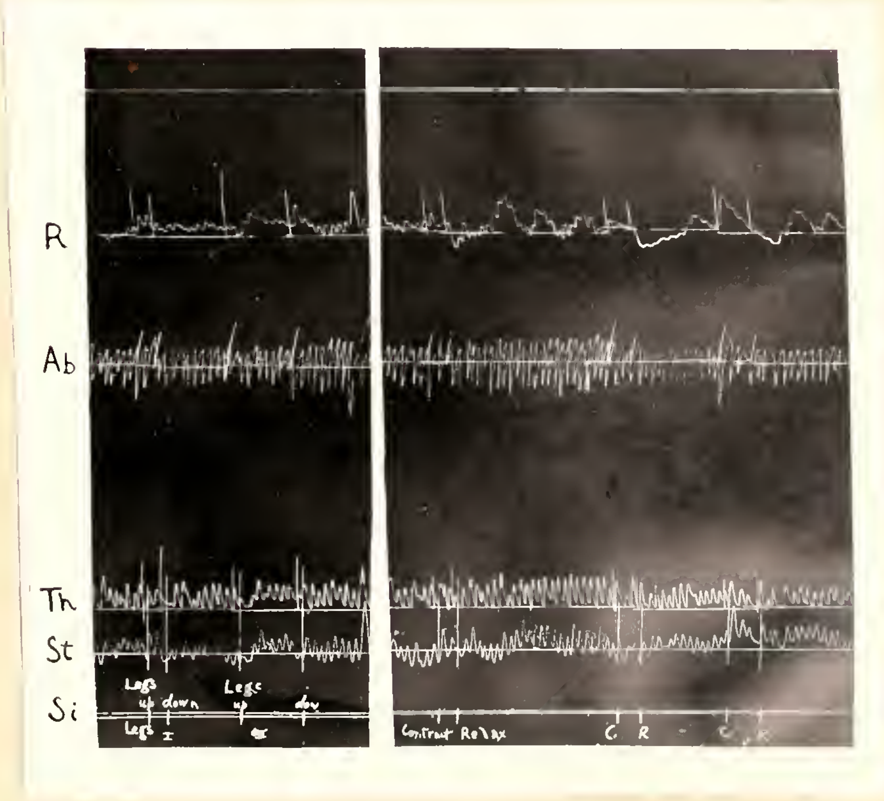
Fig. 10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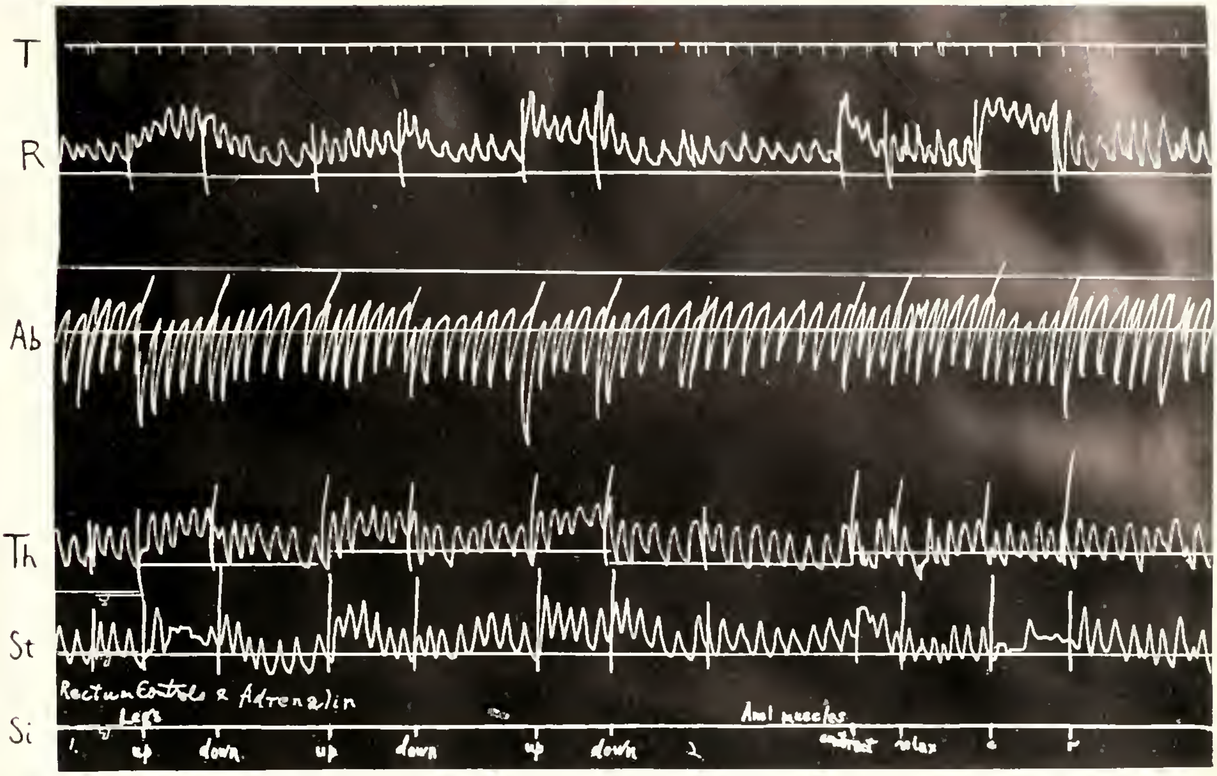
C R

Fig. 11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Rectum Controls & Adrenalin
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down
up
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2
Anal muscles
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c
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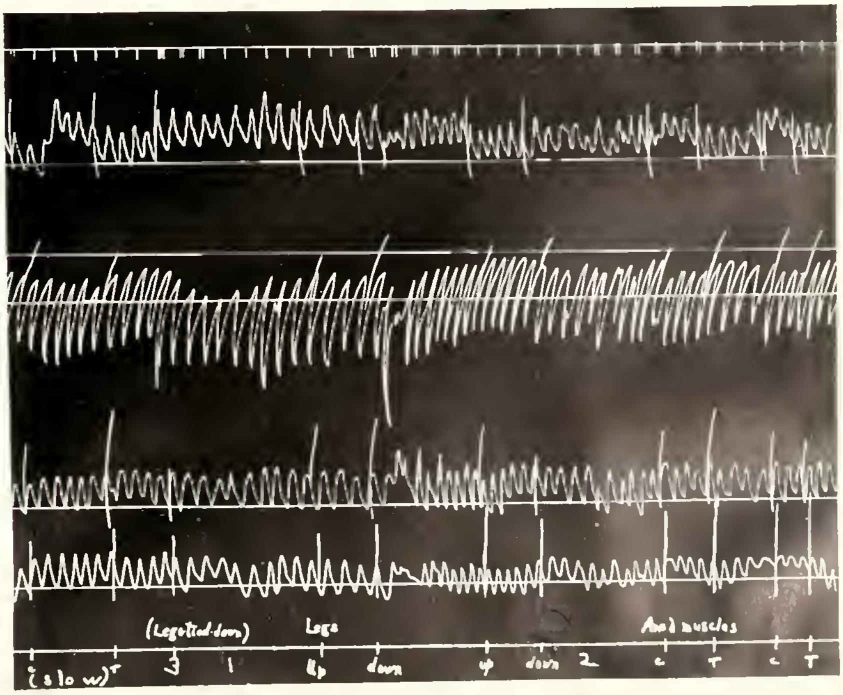
Fig. 12


(Legs tied down)
Legs
Anal muscles
(slow) r
3
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up
down
up
down
2
c
r
c
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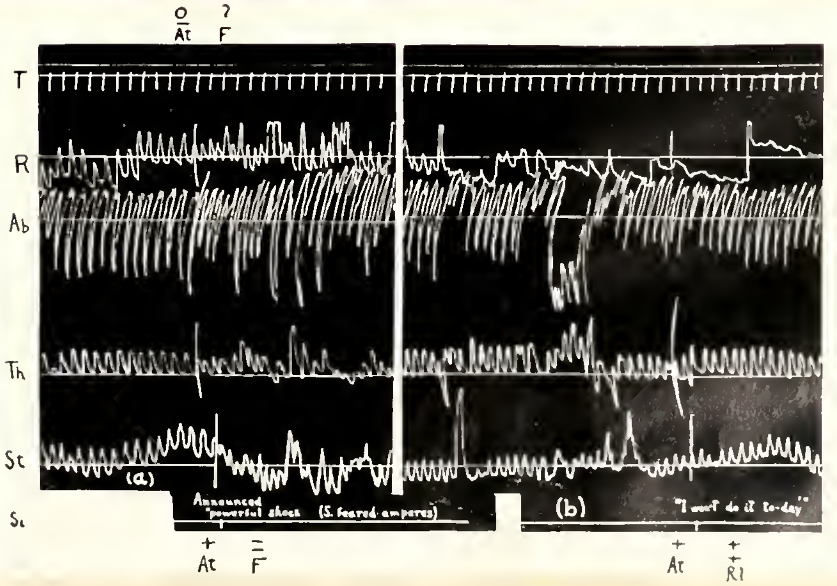
Fig. 13

Fig. 14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(a)
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Announced "powerful shock (S. feared amperes)
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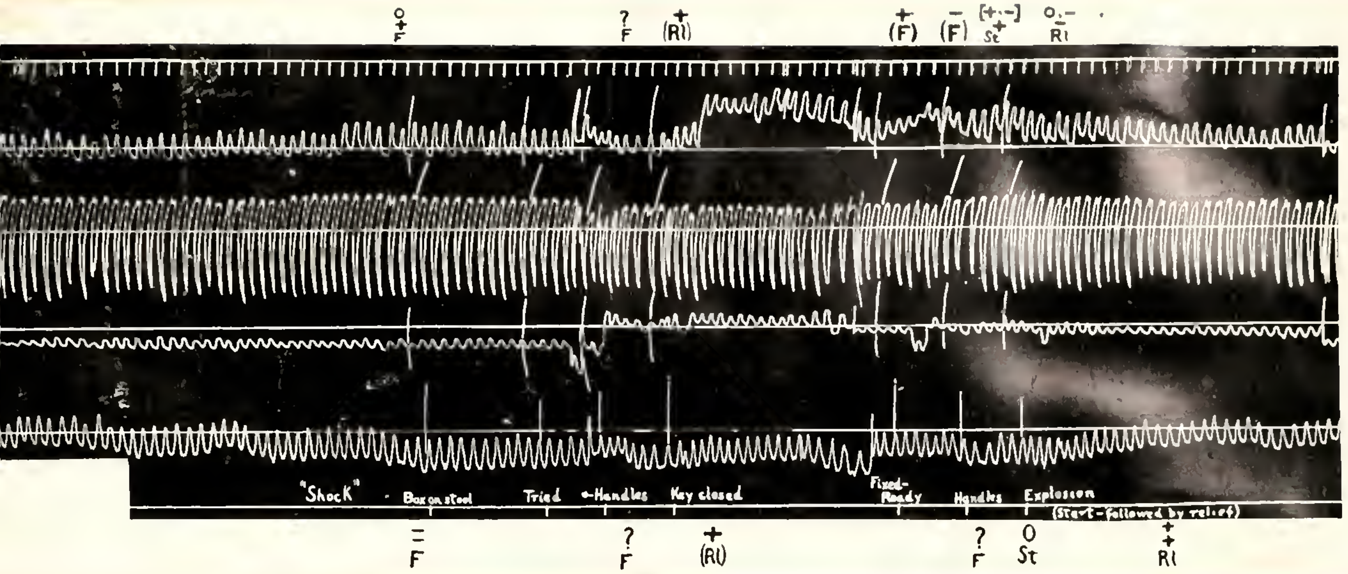
Fig. 15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Tried
←Handles
Key closed
Fixed-Ready
Handles
Explosion
(Start-followed by relief)
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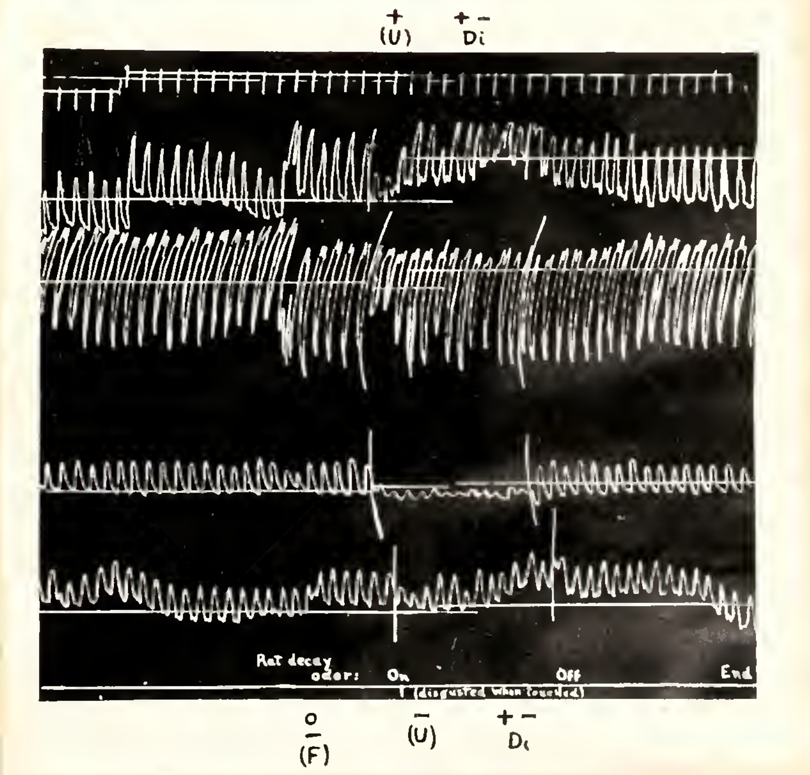
Fig. 16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Di

Fig. 17

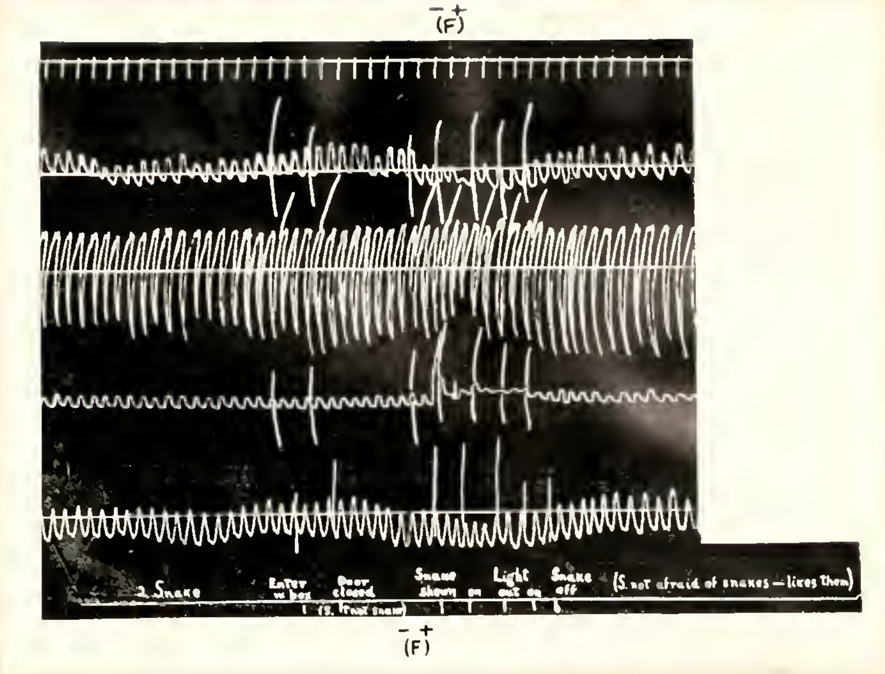

– +
(F)
2. Snake
Enter w box
Door closed
(S. "not scared")
Snake shown
on
Light out
on
Snake off
(S. not afraid of snakes — likes them)
– +
(F)

Fig. 18

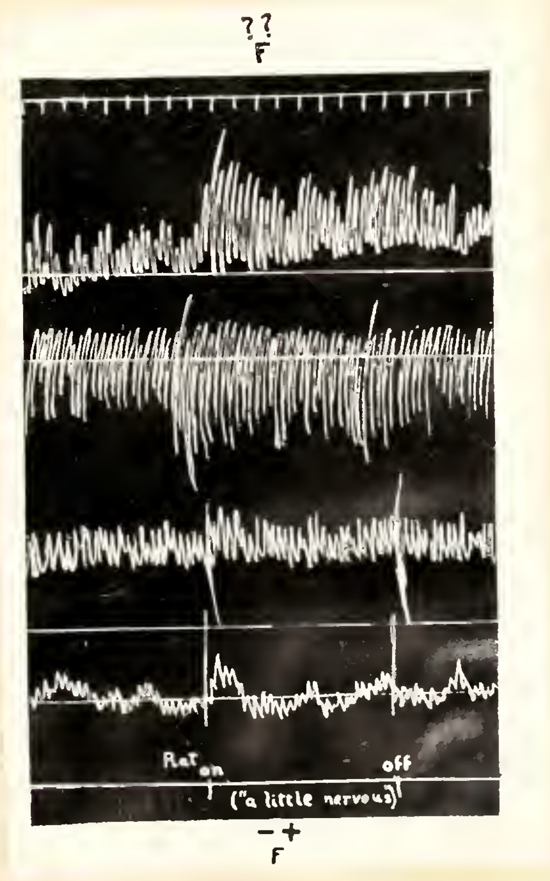

? ?
F
Rat on
off
("a little nervous)
– +
F

Fig. 19

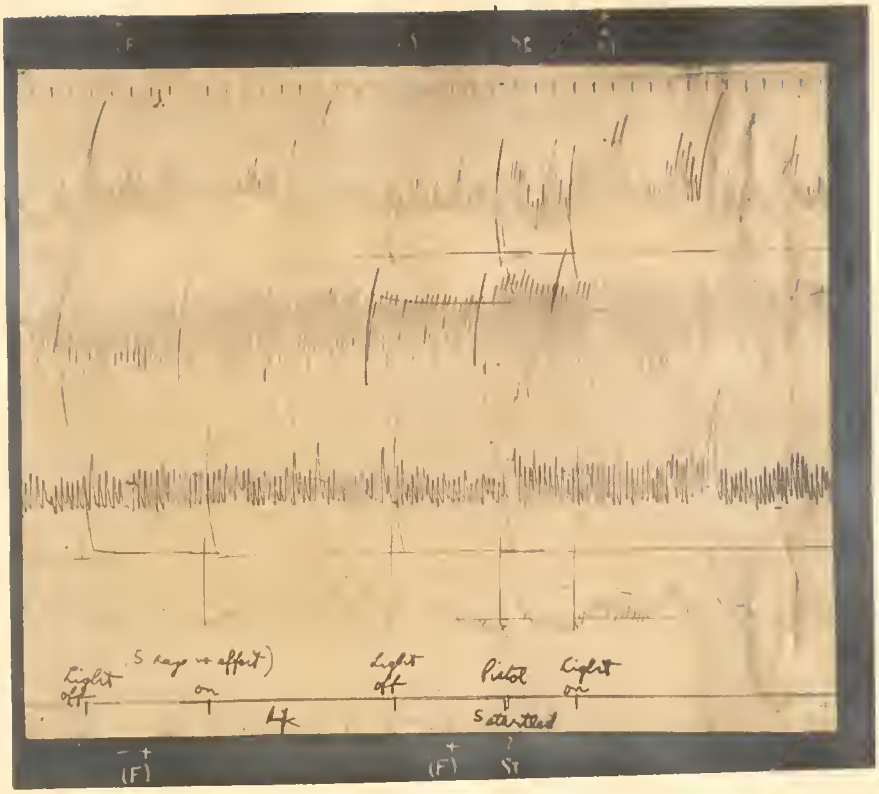

Light off
(S says no effect)
on
Light off
Pistol
Light on
4k
S startled
(F)
(F)
St

Fig. 20

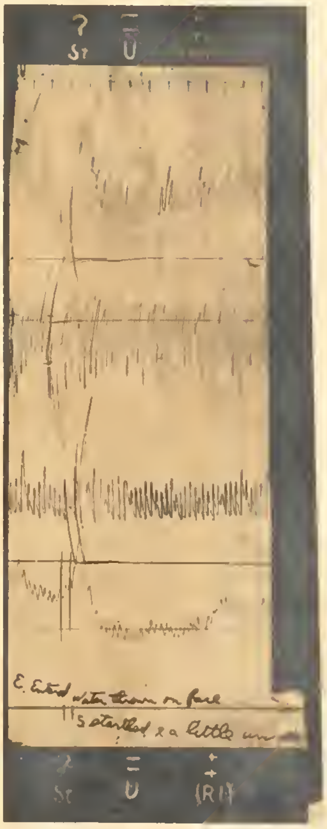
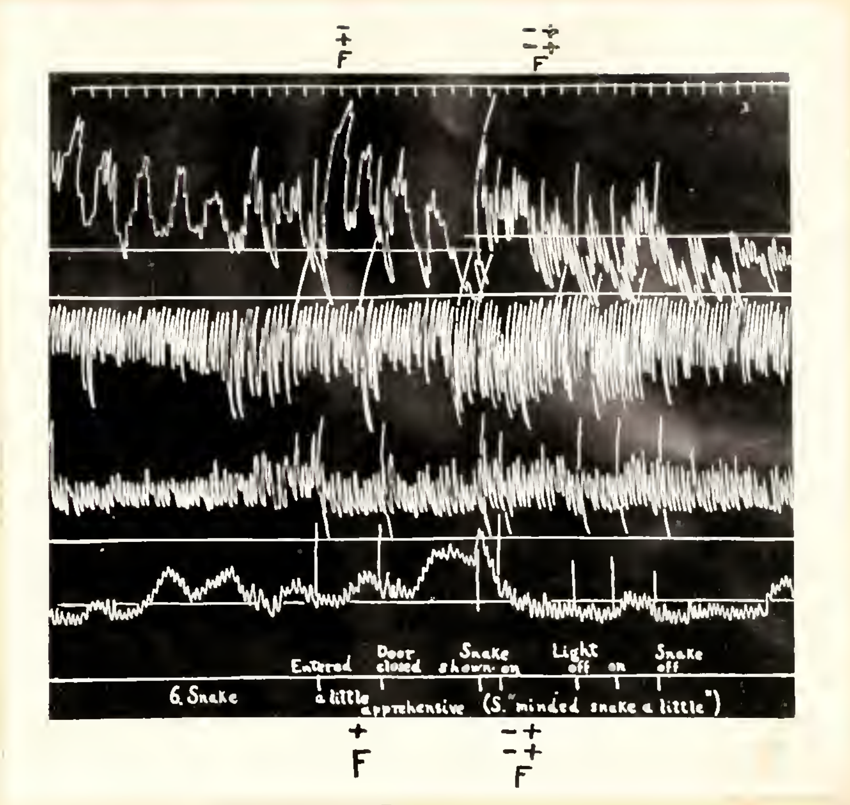
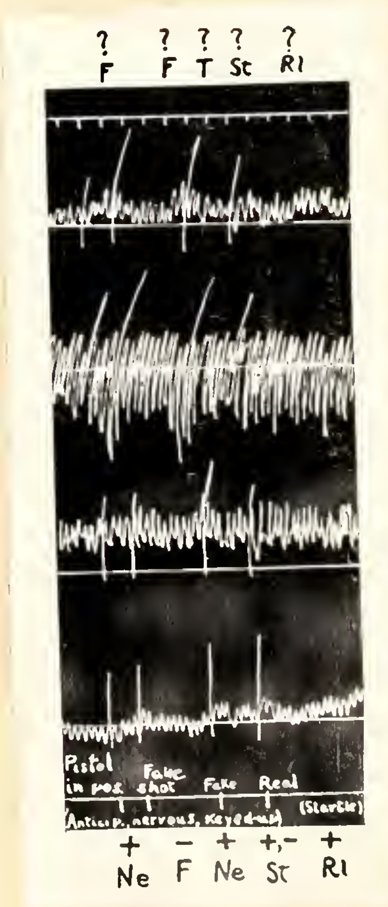

St
U
E. Entered water thrown on face
S startled & a little un
St
U
(R1)

Fig. 21



−
+
F
− +
− +
F
Entered
Door closed
Snake shown
on
Light off
on
Snake off
6. Snake
a little apprehensive (S. "minded snake a little")
+
F
− +
− +
F

Fig. 22



?
F
?
F
?
T
?
St
?
Rl
Pistol in pos.
Fake shot
Fake
Real
Anticip. nervous, keyed-up
(Startle)
+
Ne
−
F
+
Ne
+,−
St
+
Rl

Fig. 23

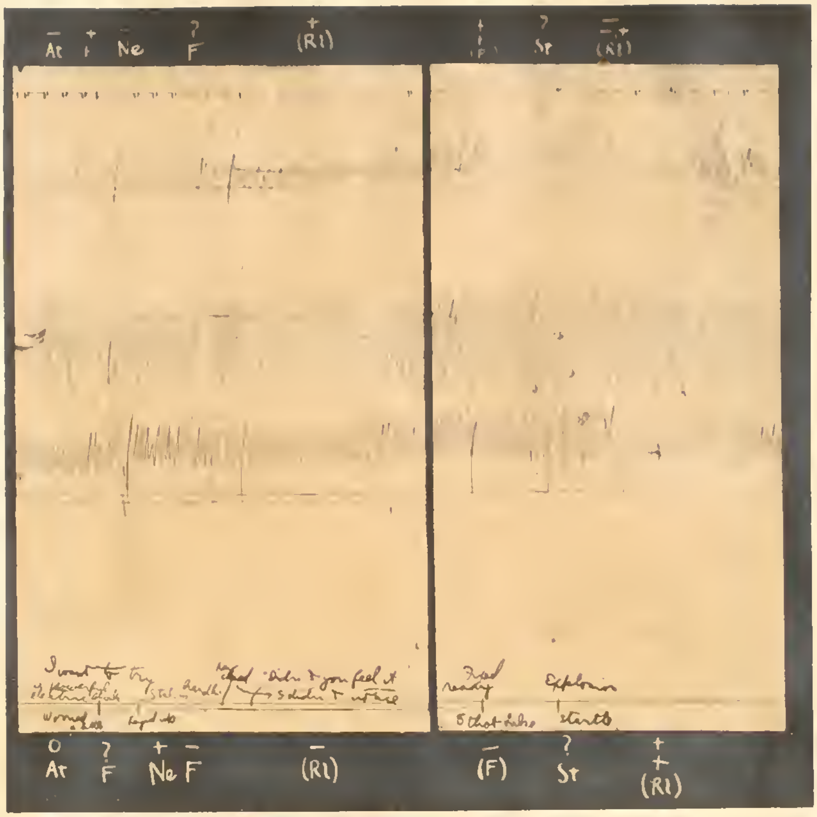

At
F
Ne
F
(Rl)
F
St
(Rl)
I want to try
you feel it
Feel ready
Explosion
starts
At
F
Ne F
(Rl)
(F)
St
(Rl)

Fig. 24

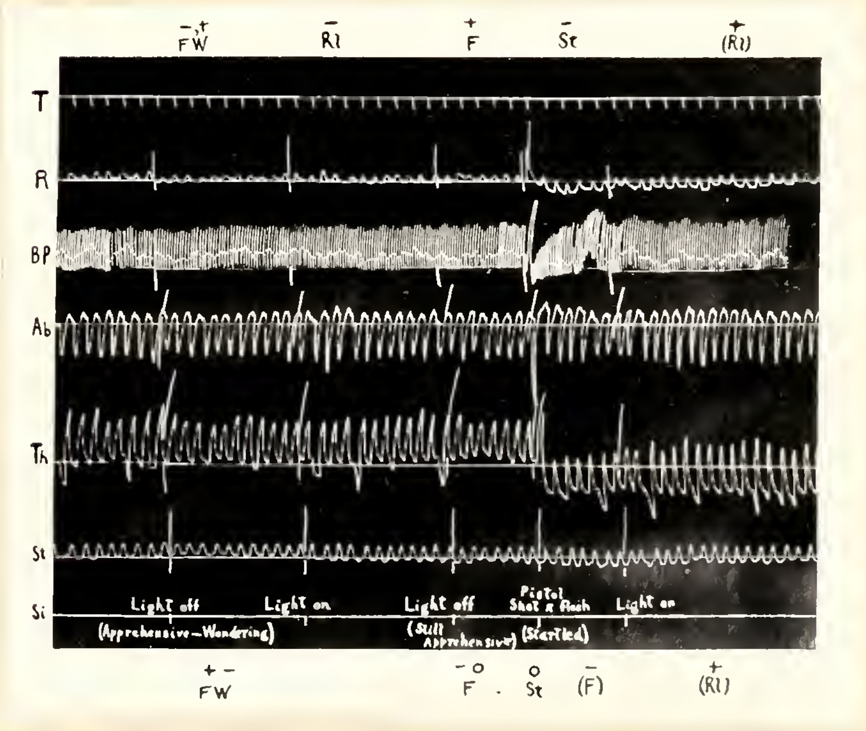

FW
Rl
F
St
(Rl)
T
R
BP
Ab
Th
St
Si
Light off
Light on
Light off
Pistol Shot & Flash
Light on
(Apprehensive–Wondering)
(Still Apprehensive)
(Startled)
FW
F
St
(F)
(Rl)

Fig. 25

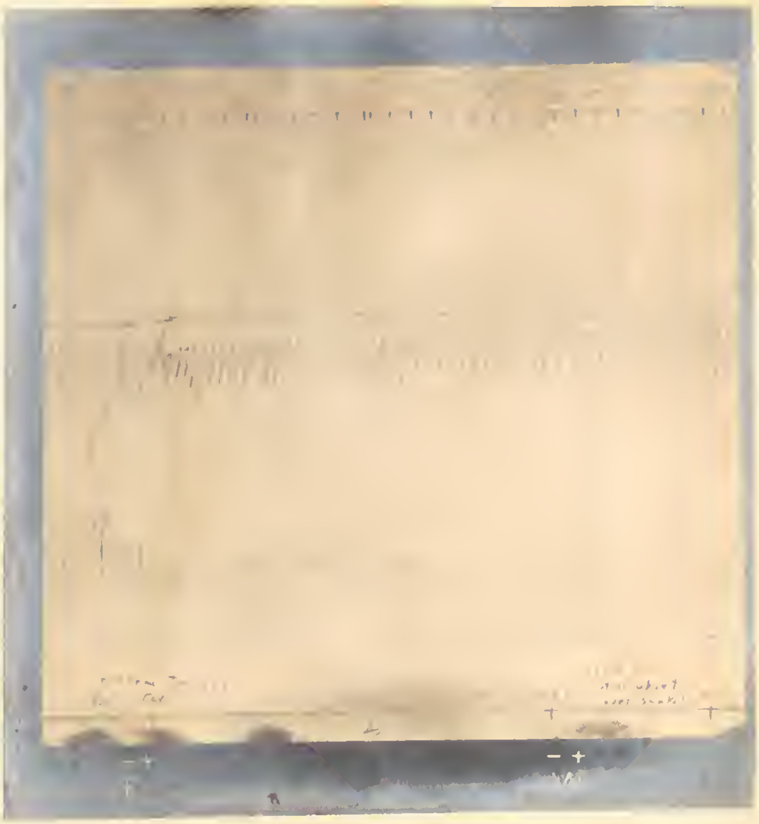


Fig. 26

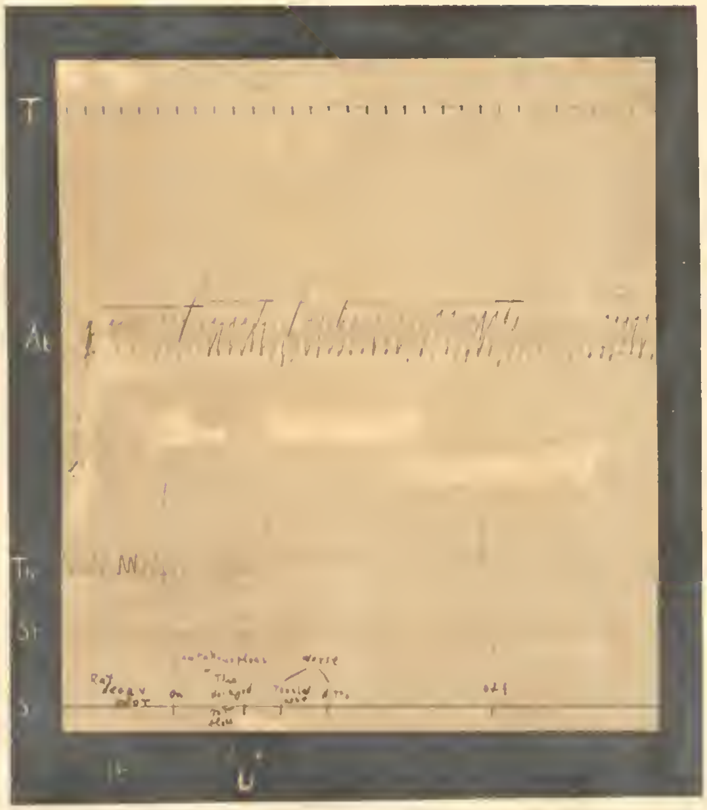


Fig. 27

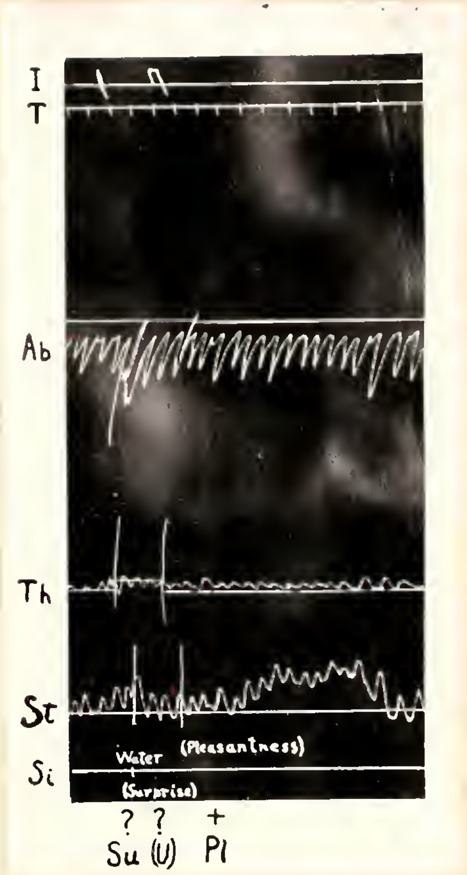


Fig. 28

Fig. 29

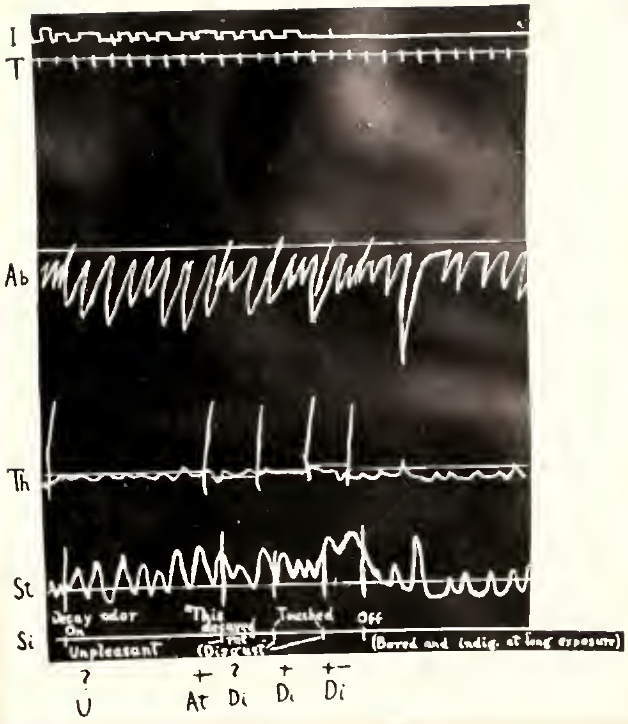

I
T
Ab
Th
St
Si
Decay odor
On
Unpleasant
"This
disgusts
me"
(Disgust)
Touched
Off
(Bored and indig. at long exposure)
?
U
+
At
?
Di
+
Di
+−
Di

Fig. 30

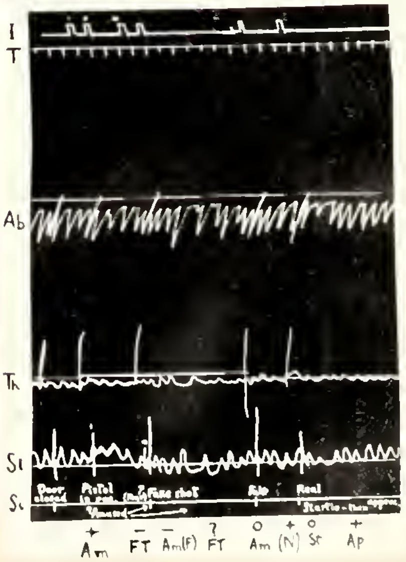

I
T
Ab
Th
St
Si
Door closed
Pistol
Fake shot
Amused
Real
Startle - then approp.
+
Am
−
FT
−
Am(F)
?
FT
○
Am
+
(N)
○
St
+
Ap

Fig. 31

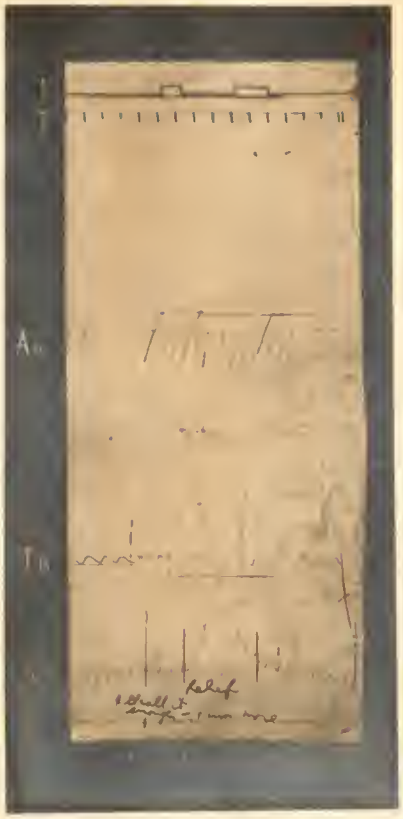

Ab
Th
relief

Fig 32

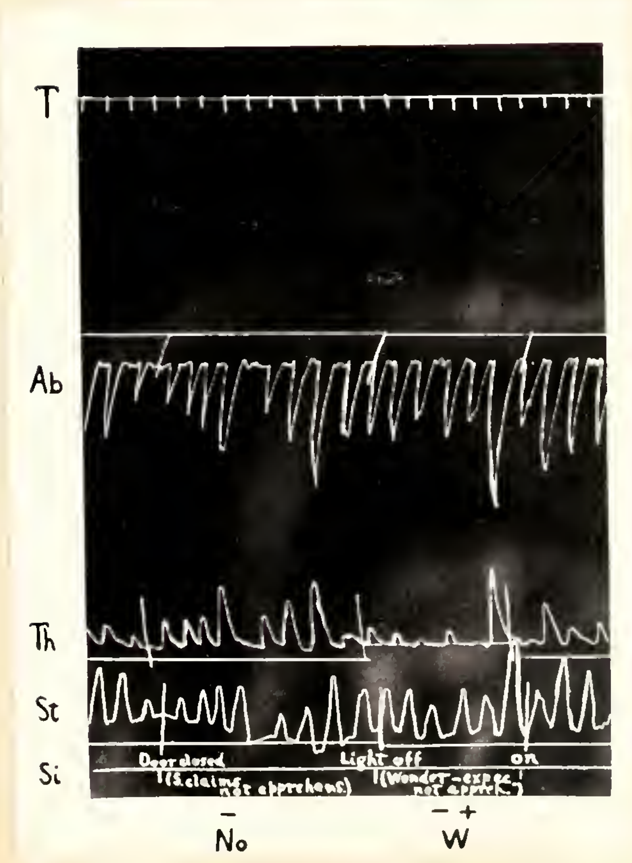

T
Ab
Th
St
Si
Door closed
(S. claims not apprehens.)
Light off
(Wonder - expec. not apprek.)
on
–
No
– +
W

Fig. 33

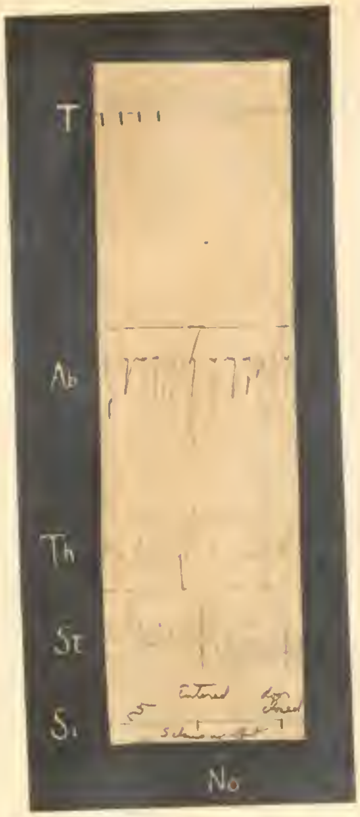

T
Ab
Th
St
S
Entered
dog
closed
No

Fig. 34

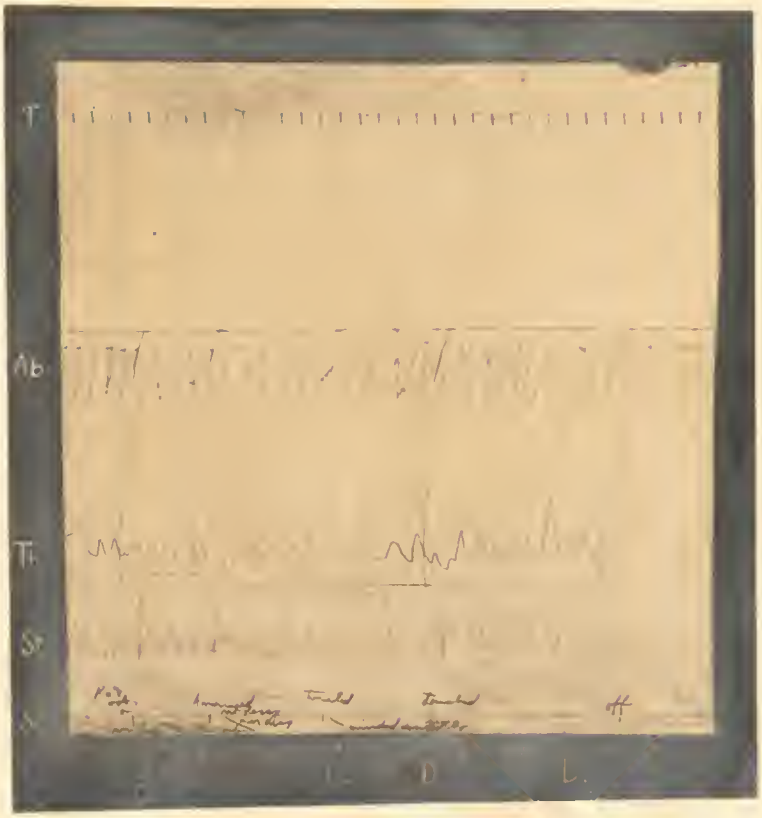

T
Ab
Th
St
S
touched
touched
off

Fig. 35

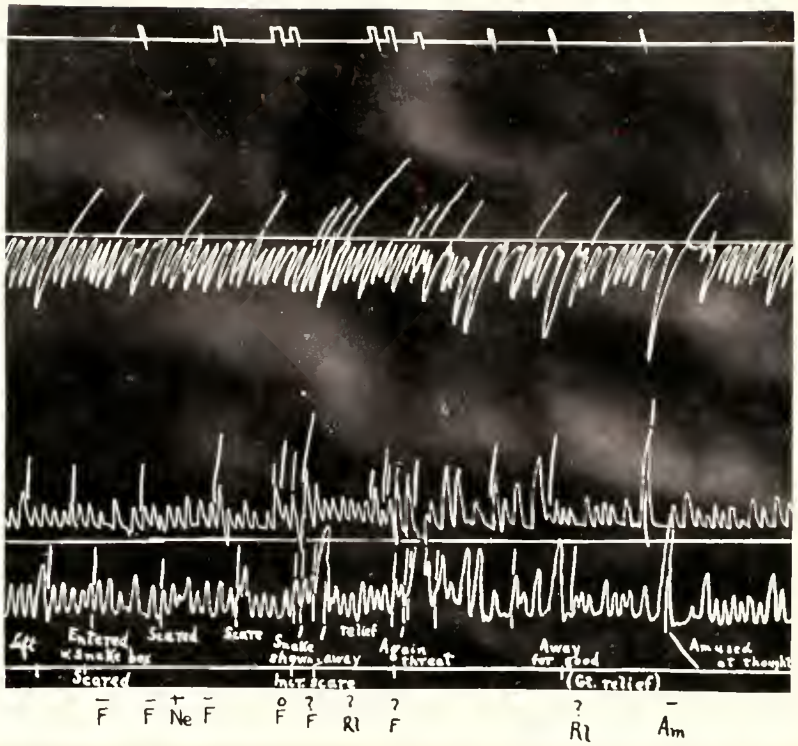

Lft
Entered
snake box
Scared
Scared
Scare
Snake
shown, away
Incr. scare
relief
Again
threat
Away
for good
(Gt. relief)
Amused
at thought
F
F
Ne
F
F
F
Rl
F
Rl
Am

Fig 36

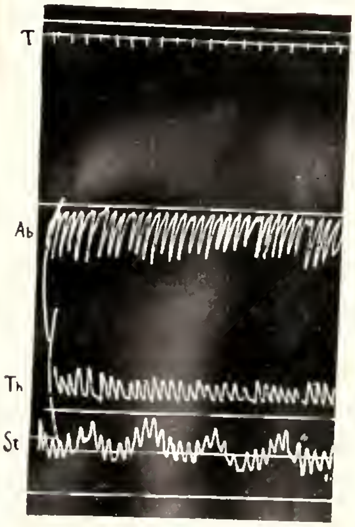

T
Ab
Th
St

Fig. 37

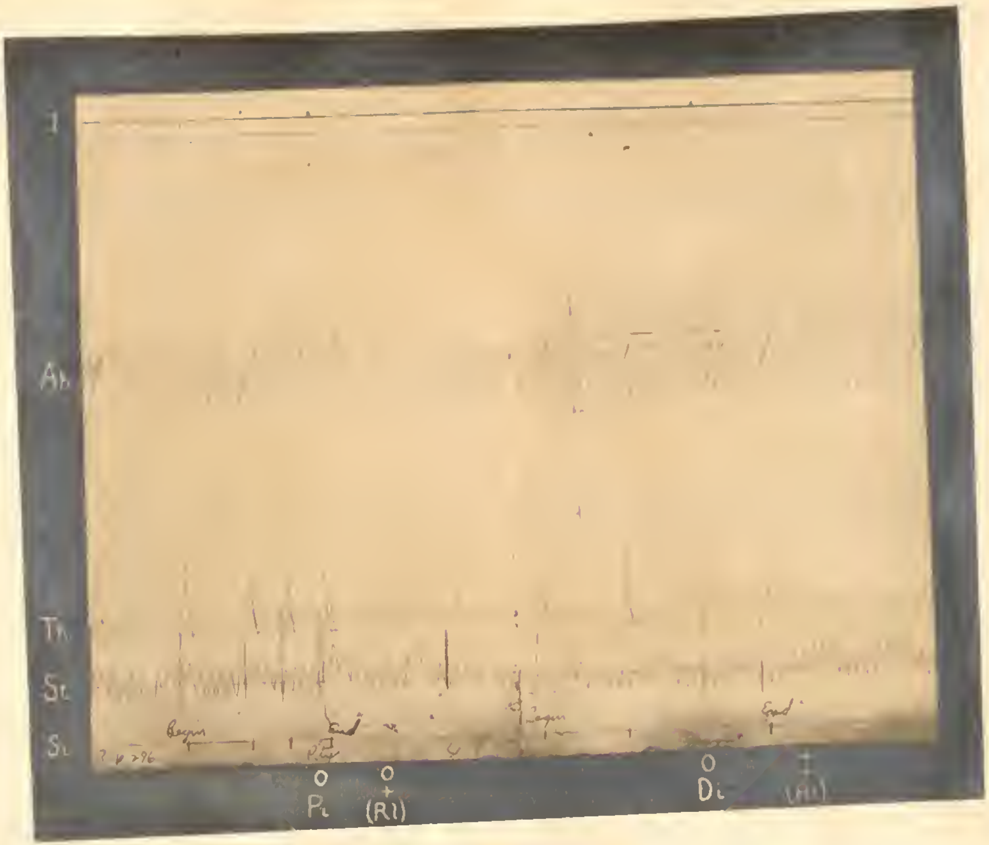

I
Ab
Th
St
Si
Begin
End
Begin
End
O
Pi
O
+
(RI)
O
Di
+
(RI)

Fig. 38

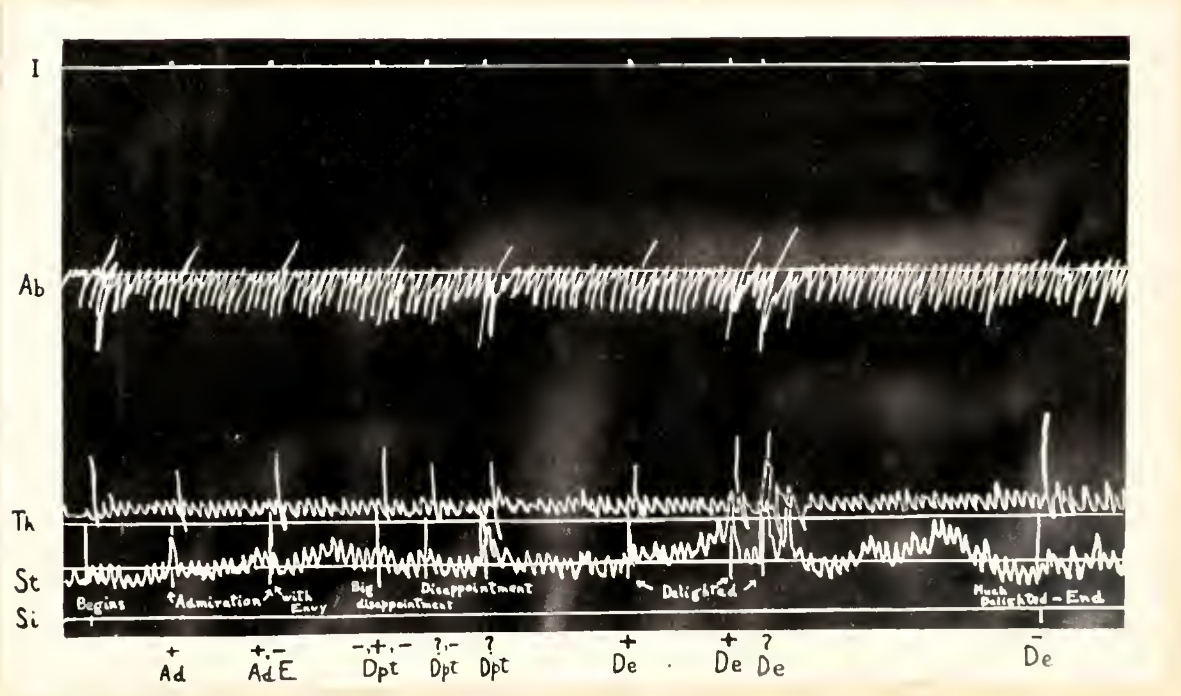

I
Ab
Th
St
Si
Begins
Admiration
with Envy
Big disappointment
Disappointment
Delighted
Much Delighted - End
+
Ad
+,–
Ad E
–,+,–
Dpt
?,–
Dpt
?
Dpt
+
De
+
De
?
De
–
De

Fig. 39

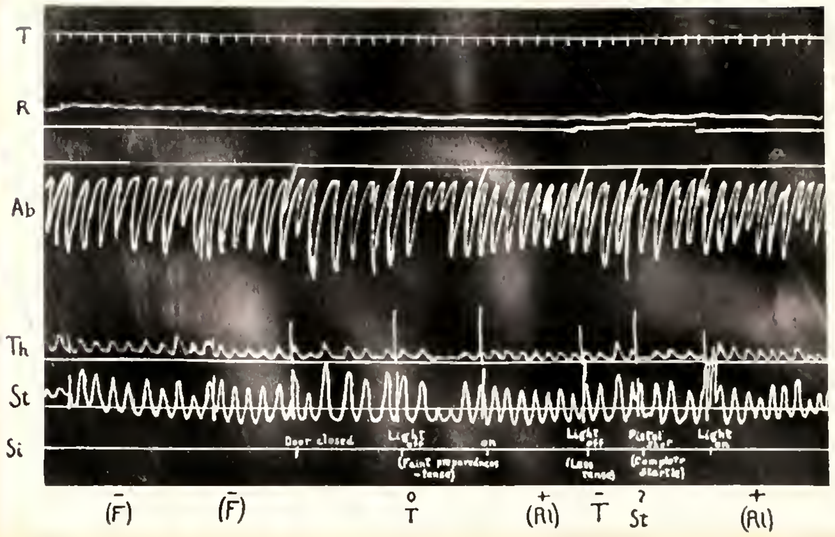

T
R
Ab
Th
St
Si
Door closed
Light off
on
(Faint preparedness - tense)
Light off
(Less tense)
Pistol shot
(Complete startle)
Light on
$\bar{(F)}$
$\bar{(F)}$
$\overset{0}{T}$
$\overset{+}{(Al)}$
$\bar{T}$
$\overset{?}{St}$
$\overset{+}{(Al)}$

Fig. 40

T
Ab
St
$\overset{+}{A}$ $\overset{-}{U}$

Fig. 41

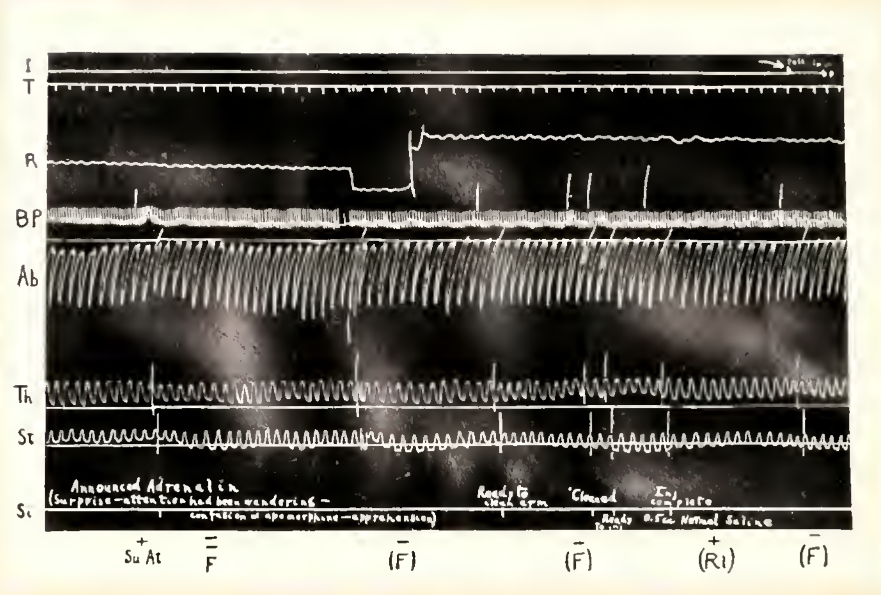

I
T
R
BP
Ab
Th
St
Si
Announced Adrenalin
(Surprise—attention had been wandering—
confusion w apomorphine—apprehension)
Ready to clean arm
Cleaned
Ready to inj
Inj complete
0.5cc Normal Saline
$\overset{+}{Su}$ At
$\overline{\overline{F}}$
$(\overline{F})$
$(\overline{F})$
$(\overset{+}{Ri})$
$(\overline{F})$

Fig. 42

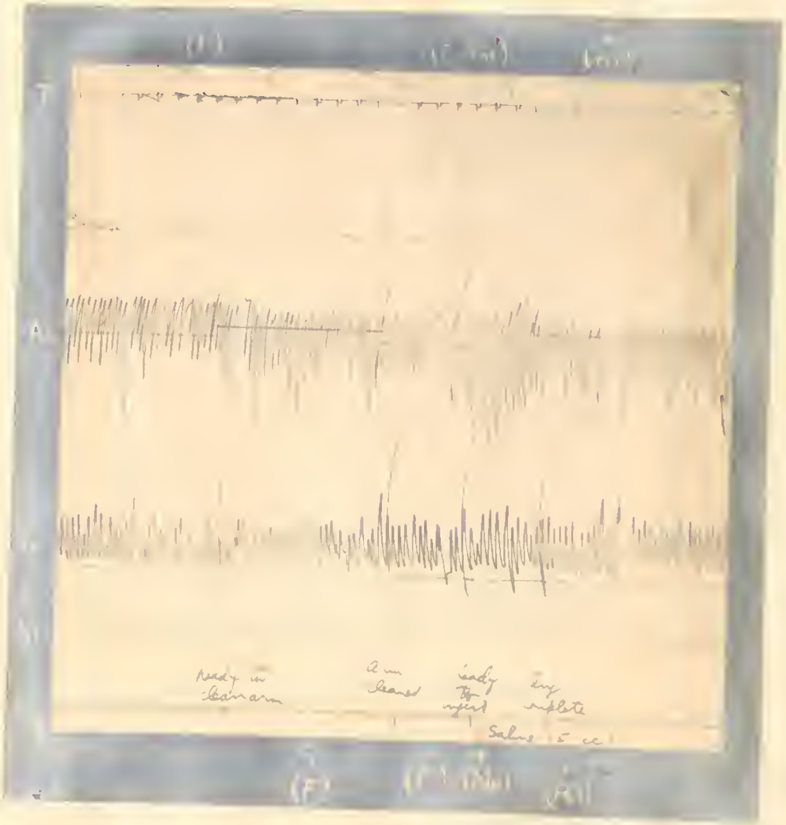

T
A
Ready to clean arm
Arm cleaned
Ready to inject
Inj complete
Saline .5 cc
(F)

Fig. 43

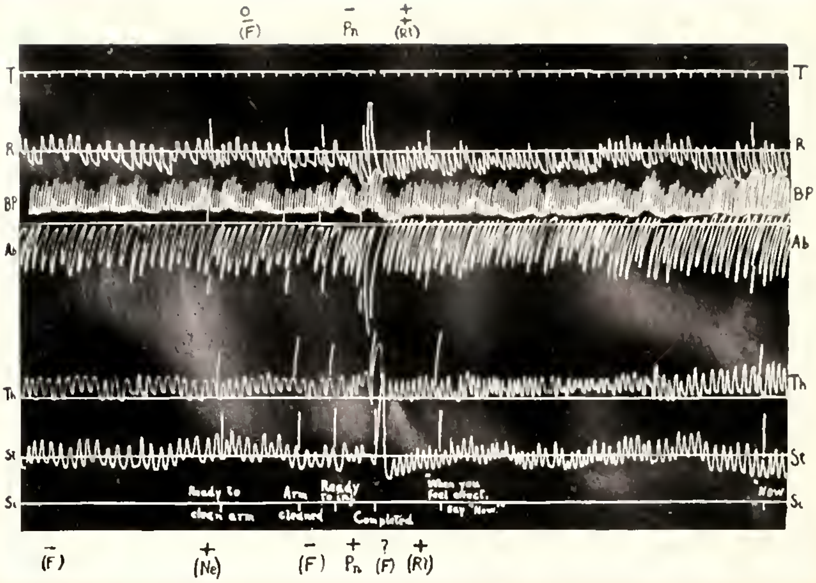


Fig. 44

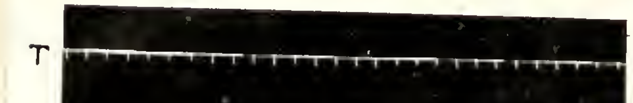


Fig. 45

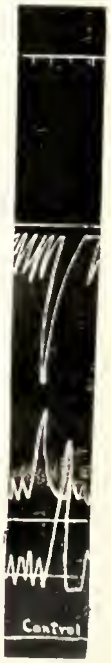


Fig. 46

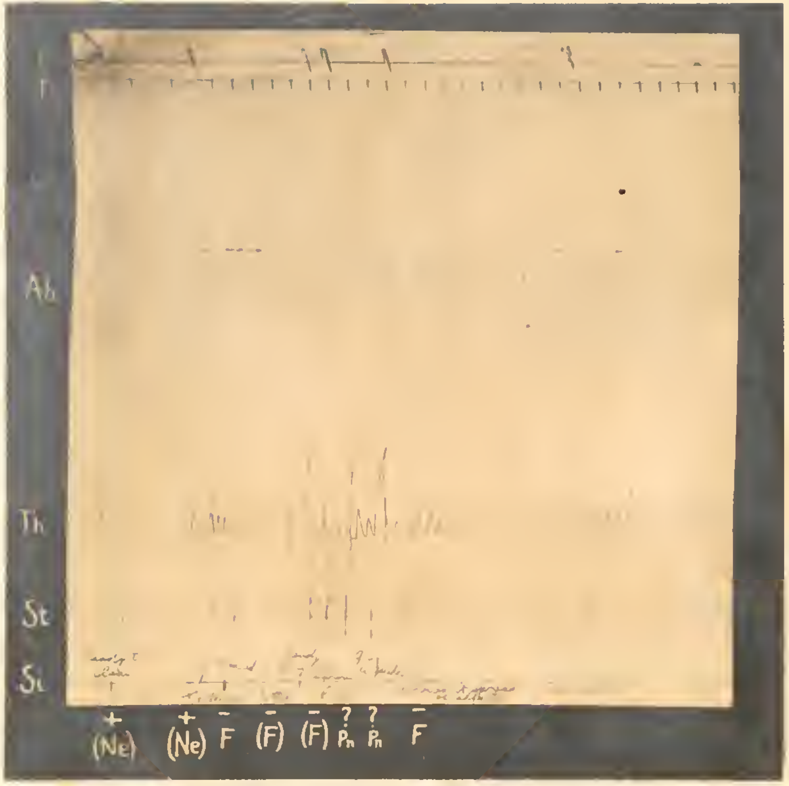


Fig. 47

Fig. 48

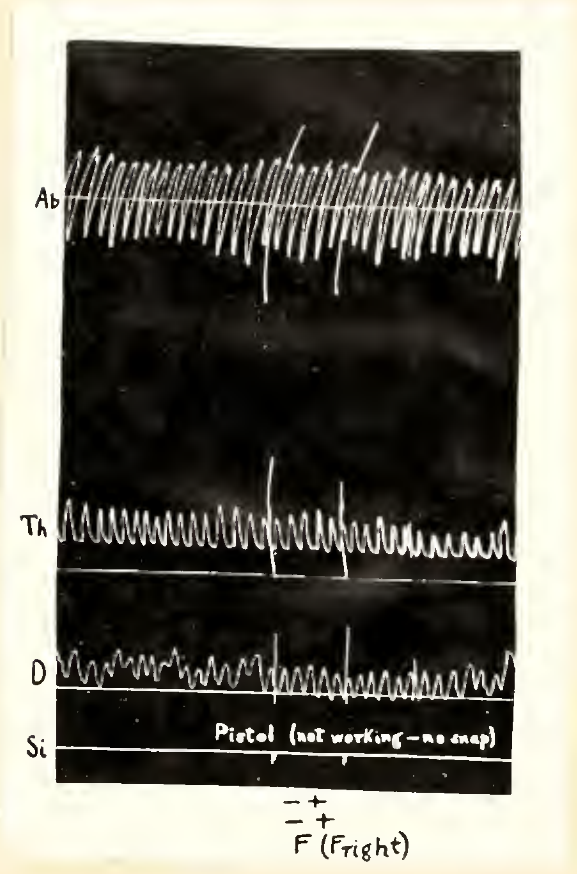


Fig. 49